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COMPARATIVE PSYCHOLOGY MONOGRAPHS

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The Effects of Cumulative Training Upon Retroactive Inhibition and Transfer

MELVIN H. MARX

University of Missouri

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THE EFFECTS OF CUMULATIVE TRAINING UPON RETROACTIVE INHIBITION AND TRANSFER¹

MELVIN H. MARX

University of Missouri

CONTENTS

Introduction.....	1
Problem and procedure	8
Results.....	13
1. Cumulative transfer in the learning of twelve successive mazes.....	13
2. Cumulative transfer and retroactive inhibition in the relearning of a difficult maze problem, learned to mastery.....	22
a. Retroactive inhibition: maze A.....	22
b. Cumulative transfer: maze A.....	29
c. Relationship between cumulative transfer and relearning efficiency: maze A..	32
3. Cumulative transfer and retroactive inhibition in the relearning of an easy maze problem, incompletely learned.....	36
a. Retroactive inhibition: maze B.....	36
b. Cumulative transfer: maze B.....	44
c. Relationship between cumulative transfer and relearning efficiency: maze B..	47
Discussion of results.....	50
Summary and conclusions.....	59
References.....	60

INTRODUCTION

Experimental work in the field of memory within recent years has led to the view that retroactive inhibition is the major conditioning factor in forgetting. In development of this point of view considerable emphasis is usually placed upon the amount of interpolated activity, as one of the primary factors in determining the amount of retroactive inhibition, or forgetting. Very great theoretical interest attaches to this variable because of its importance as a principal attribute of the activities which produce interference in memory, and because of its inevitable increase in magnitude as the interval over which memory is measured becomes progressively longer. Hunter, for example, recognized it in 1929, noting (14, p. 599; also, McGeoch, 17) that "the loss of retention varies with the lapse of time; but, as the lapse of time increases, the quantity of interpolated activity also increases. It is to the latter factor that we must look for an explanation of the loss."

It is surprising, in view of this theoretical interest, that so little experimental work has been done on this variable. All told, there have been no more than a dozen studies which are at all directly related to the problem of the influence on retention of the *quantity* of interpolated material. (See reviews by Britt, 1, Swenson, 29, and McGeoch, 20, p. 472 ff.) The majority of these also involve

¹ This monograph represents the major part of a Ph.D. thesis prepared at Washington University under the direction of Professor M. E. Bunch, for whose critical supervision and constant encouragement the writer wishes to express grateful acknowledgment.

degree of learning, either explicitly or actually as a result of the manner in which amount of interpolated activity was increased. In these studies only a single task is provided for the interpolated learning activity. Degree of learning and amount of interpolation is then varied in one of two ways: (1) by increasing the number of presentations of the task, or learning trials; or (2) by increasing the amount of time to be spent in learning the task. There have been only two experiments in which the variable of amount of interpolated learning has been effectively isolated. McGeoch (21) has doubled the length of the interpolated problem, varying the frequency of presentation for each length problem so as to control degree of learning. Twining (30) alone has introduced several different interpolated problems, producing an increase in quantity of interpolation which is relatively independent of the degree of learning of any single task. It is probable that extent of activity rather than degree of learning is the more important variable in normal everyday forgetting, and that unless it is isolated from the closely related factor of degree of learning, its special influence upon retroactive inhibition and therefore its general theoretical significance in forgetting, will be difficult to determine.

Those studies which emphasized degree of learning as the experimental variable, but which also necessarily varied amount of interpolated learning activity, may be briefly considered. McGeoch (18) found that 6 interpolations of nonsense syllable lists produced less retroactive inhibition than 11, 16, 21 or 26, and that there was no consistent variation for the latter frequencies. Melton and Irwin (25), repeating this experiment with some modifications, obtained a regular increase in retroaction by all measures with early increases in frequency of presentation of the interpolated list, and were able to show a significant *decrease* in retroaction with a very high frequency (40 trials). In a recent study of this sort Thune and Underwood (29) again found the progressive increase in retroaction with low frequencies but were unable to confirm the later decrease, possibly because their maximum frequency of presentation of the interpolated list was only 20. Ho (13) has reported a study from the animal field which, although evidently not planned as an experiment on retroactive inhibition, involved original learning of a maze by white rats, varying amounts of practice on a second (interpolated) maze, and relearning of the first maze after an interval of twenty days. The poorest retention was found in the control, or rest, group. The differences were slight and probably insignificant for the first relearning trial, but were large and without exception in terms of total relearning scores.² While these results appear to be inexplicable on the basis of generalizations from the corresponding studies on human verbal learning, they may not be quite as contradictory as they seem and they will be considered again in discussion of the results of the present experiment.

In the studies thus far reviewed degree of learning of the interpolated task was successfully varied by increasing the frequency of presentation of the problem. Although these studies have generally emphasized the factor of degree of learn-

² For example, the savings in trials were, for 0, 5, 9, 15, 25 and 35 interpolated trials, 69, 90, 82, 91, 97, and 96 per cent respectively.

ing, and have attributed the progressive rise and subsequent decline in retroactive inhibition to this factor, there is a possibility that some of the effect, at least, might be a function of amount of interpolated activity, since this is unavoidably a concomitant variable under the circumstances. Experimental support for this possibility is supplied by McGeoch (18), who tested the influence of degree of learning by both the anticipation and the complete presentation methods. When he varied the frequency of presentation of the interpolated list, he found that the mean number of correct anticipations of that list increased regularly with each increase in frequency, and he could therefore attribute his results to the factor of degree of learning. When, however, he used the method of complete presentation and attempted to increase degree of learning by extending the duration of the time interval allotted to study of the interpolated list, he found that the mean number of nonsense syllables correctly recalled from the interpolated list did not increase uniformly with increase in the length of the study period. Nevertheless, retroactive inhibition did show a regular increase. Finding that his data were sufficiently consistent to indicate some regular influence, but that they could not be made a function of the intended variable because it apparently had not correspondingly varied, McGeoch was forced to the non-committal conclusion (18, p. 704) that "evidently factors not measured by immediate recall are involved." He did suggest that the obtained results may be a "function of mere time spent in effort as well as of presumably more important factors" (18, p. 705). There is, of course, no direct evidence that quantity of activity was the effective variable in this study, but it is reasonable to suppose that, as the length of the interpolated learning interval was increased, there was a corresponding increase in the amount of the activity which had been designed to produce retroaction, and hence a greater opportunity for the action of interference factors.³

In the first experiment in which amount of interpolated activity was clearly isolated as the major variable,⁴ McGeoch (21) provides additional support for this point of view. With original learning limited to 8 repetitions of lists of 16 two-syllable adjectives and interpolated learning for 4, 8 and 16 repetitions of 8 or 16 adjective lists, the longer interpolated list produced for all frequencies

³ Other studies using the method of complete presentation have been reported by Foucault (11) and Lahey (15), but they do not contribute much to this aspect of the problem. As early as 1913 Foucault found indications of increased retroactive effect with greater amounts of interpolated learning, for two subjects fully reported and three time intervals. More recently Lahey, in a much more systematic experiment, used over three thousand grade school children and several time intervals. She reports a progressive increase in retroactive effect with increasing time spent in interpolated learning, up to the maximum of fourteen minutes, with no decline for the longer intervals. Since she provides no information as to the extent of the interpolated learning under the various experimental conditions, it is not possible to determine how successfully this factor was actually varied.

⁴ Bunch and McTeer (9) and Britt and Bunch (2), noting that the decrease in retroactive inhibition produced by their main variables (punishment by shock and age of associations, respectively) was accompanied by a lesser amount of interpolated learning activity, had previously suggested that the latter factor may have been responsible for at least a part of the reduction.

greater retroactive effect than was found for any frequency of the shorter list. The inference from this result is obvious. If under these circumstances variation of the amount of material to be learned, and thus of the amount of interpolated activity, can be a more important factor than frequency of presentation, and thus degree of learning, it is clear that similar increases in the amount of interpolated activity may have been more effective factors than was realized in the production of results specifically attributed to the degree of learning variable.

The first and only study designed to increase quantity of interpolated learning activity by systematically varying the number of interpolated learning tasks—rather than the trials or time spent on a single task—has been reported by Twining (30).⁵ Using lists of eight nonsense syllables, he permitted his subjects to learn the original problem to mastery and then interpolated from one to five lists for ten trials each. The mean recall scores and mean relearning trials from one through five interpolated problems were, respectively, 1.40, 1.13, 0.41, 0.27 and 0.07, and 5.53, 6.93, 9.74, 11.33 and 13.53.⁶ The decrement produced in retention, with the time interval held constant at thirty minutes, thus varied directly with the number of interpolated tasks. When degree of learning and quantity of interpolated activity are both variables (18, 25) a progressive increase in retroaction and a subsequent decline have been definitely established. When quantity of interpolated material is a variable but degree of learning is doubtful (15, 18, 30), the original increase but not the later decline has been established.

If there is a progressive and continuous increase in amount of retroactive inhibition with increasing amount of interpolated learning activity, the theoretical position of retroactive inhibition as the major condition of forgetting is considerably strengthened. If, on the other hand, the retroactive effect from continued accumulation of interpolated learning activity reaches a maximum after a certain quantity of interpolation and additional amounts produce either no additional retroaction, or even a declining amount of retroaction, then it is obvious that there are limiting factors to the amount of interference that can be produced in memory by interpolated learning. Such limiting factors must be taken into account in any theoretical explanation of the basis of normal forgetting, whether of artificial laboratory materials or of everyday experiences.

Some experimental evidence that there are such limiting factors in the amount of retroactive inhibition that may be produced under certain conditions of interpolation has been provided by Bunch (5). Using human subjects and rational learning problems, he found that when an interpolated problem immediately

⁵ Vélinsky (31) has reported an experiment in which he varied the number of interpolated units as well as the length of the interval between arbitrary products and arithmetic figures (e.g., $19 \times 86 = 459$) which were to be associated. Since increased repetitions were required for learning under conditions of longer intervals but not under conditions of more interpolated units, he concluded that the interference in memory was greater under the former conditions. In view, however, of the complicated and rather restricted circumstances of the experiment, generalizations based upon these results must be regarded with considerable caution.

⁶ Since Twining had in this experiment no rest condition with which to compare the various work conditions, percentages of retroaction cannot be directly computed.

preceded relearning of the original, retroactive inhibition was clearly present with time intervals of two and fourteen days, was statistically insignificant after thirty days, and was actually replaced by a facilitating effect after an interval of ninety days. Apparently the curve for the forgetting that was brought about by the intervention of normal everyday experiences had begun to level off after ninety days. After this point further interpolation in the form of an additional problem was beneficial in relearning, although the same problem was definitely detrimental if interpolated within fourteen days after the original learning.

Adequate interpretation of this result seems to be possible only in terms of transfer of training. It is the varying relationship which exists between the original and the interpolated learning activities that is directly responsible for the variation in efficiency of relearning at the time of the second test. When this relationship is changed, as by varying the temporal conditions in the experiment just cited, corresponding changes may be expected in the amount of retroactive inhibition that appears in retention. In the present study the factor used to vary this relationship is amount of training. Since the problem is to study the effects of varying amounts of the same cumulative training upon transfer as well as upon retention, in order to gain further factual information on the relationship between the two phenomena, the pertinent literature on transfer will now be cited.

In an early experiment on transfer of training and retroaction, Webb (34) noted that one maze would transfer positively to another in the transfer situation and would transfer negatively (that is, produce retroactive inhibition) in the retroaction, or relearning, situation. He suggested a transfer theory of retroaction, which has since received so much experimental support that it is now generally accepted in some form or other. In the first experiment on cumulative transfer Wiltbank (35) also used white rats and mazes, with learning of five consecutive problems followed by relearning of the first. His results, however, were inconclusive. More recently, Bunch and Winston (10) found that in human learning with nonsense syllables amount of retroactive inhibition tends to vary with the character of the transfer from original to interpolated learning. With the amount of interpolated learning held roughly constant, the negative transfer situation resulted in the greater amount of retroaction. In 1935 McKinney and McGeoch (23) presented direct evidence of transfer in the form of "overt intrusions," adjectives from the interpolated list which were carried over, incorrectly, into the recall of the original list. They estimated that about twenty-five per cent of the retroactive effect might be attributed to such overt intrusions and that the remainder was probably due to implicit or partial intrusions and the interference effects they produced indirectly in recall. In one of the several important investigations stimulated by this study Melton and Von Lackum (26) report that learning of a second list—either as a prior or as an interpolated task—aided relearning of the original to mastery when the two lists were dissimilar (formed of different consonants), but produced inhibition when the two lists were similar. Negative transfer was found to a significant degree when the two lists were similar, but not when they were dissimilar. Melton and Von

Lackum conclude (26, p. 167) that "it is probable that the learning of the additional lists for five trials produced a general positive transfer (practice) effect in all work-conditions which was not present in the rest-conditions, and that the negative transfer . . . more than counterbalanced the positive transfer effect only when the two lists were similar."

The many important studies on the similarity factor in retroaction obviously have a direct bearing on the present problem. Recent results of Lin (16) and Matousek (24) agree in indicating an increased retroactive effect on retention when the interpolated material contains identical stimulus but different response terms. While there was apparently no direct measurement of actual transfer effects in these experiments, the results tend to confirm the findings by Bunch and Winston (10) of a greater retroactive effect in the negative transfer situation. This follows from the fact that the stimulus-response relationship obtaining in these experiments is the one which has been amply demonstrated as most likely to produce negative transfer in learning (*cf.* especially Bruce, 4). Similar support may be adduced from the "reproductive inhibition" experiment of McGeoch, McKinney and Peters (22), although they were unable to find as much negative transfer ("associative inhibition") as might have been expected. Gibson (12) has likewise reported an experiment in which there was a direct correlation between difficulty of learning interpolated lists of paired associates and amount of retroactive inhibition in retention (both associated, according to the author's interpretation, with increased degree of generalization between the two tasks). Watson (33), in an experiment well designed to compare the curves of transfer and retroaction as they vary with different degrees of similarity (of material and pattern of response in card sorting), has found a rough but essential correspondence between the two effects.

In the light of these results the usual difference found between recall and relearning scores as measures of retroaction takes on added significance. From the earliest reports recall scores have consistently shown greater interference effects than have relearning. McGeoch (21) and Melton and Irwin (25) have even reported facilitating effects in relearning for the same work conditions whose recall scores indicated considerable interference in retention. Furthermore, recent reports of Melton and Irwin (25) and Melton and Von Lackum (26) have suggested that the negative transfer effects are greatest on the first trial and decrease rapidly as learning progresses, disappearing entirely in the former experiment. The same tendency is observed on relearning trials, measured retroaction being greatest on the first two or three relearning trials and progressively less on succeeding trials. In confirmation of the latter results, Thune and Underwood (29) report no significant inhibition beyond the second relearning trial. Melton and Irwin (25) also note that the decrease in retroactive effect is most apparent in the relearning records of the group with the greatest frequency of interpolated trials (40), and state (25, p. 202) that this "suggests that the retroactive inhibition produced by interpolated learning disappears during relearning more rapidly the greater the degree of interpolated learning." It is again true,

however, that in this case there is not only a greater degree but also a greater *quantity* of interpolated learning. Whichever is the more effective factor in the decrease it is likely that the more rapid disappearance of the retroaction with higher frequencies of interpolation is a reflection of the changing transfer effect—a strengthening of the positive transfer factors relative to the negative. Taken as a whole, these results obviously point to the basic importance of varying transfer factors as the underlying influence in the general facilitation of retention so consistently observed in later relearning trials.

The main points of this introductory review may be summarized as follows:

1. Amount of interpolated learning, in spite of its recognized theoretical importance for the strictly behavioral theory of forgetting, has received little experimental attention as a factor in the production of retroactive inhibition.
2. Of the few pertinent studies all but two (21, 30) have failed to isolate the variable of *quantity* of interpolated activity from that of degree of learning of a single interpolated problem.
3. All studies have agreed in indicating an increase in retroaction with early increases in degree of learning, or quantity of interpolation, or both, and this has been found more consistently in recall than in relearning measures of retention.
4. In two of those studies that have varied quantity and degree of learning of interpolated material concomitantly (18, 25) there has been noticed a consistent decrease, especially in relearning scores, in retroactive effect with maximum duration of learning or frequency of presentation of the interpolated task. The two experiments (21, 30) which have isolated quantity of interpolated learning as a major variable have failed to indicate this decrease, possibly because they were not designed to check it and because they did not carry the quantity variable sufficiently far.
5. When the cumulative activities of normal living have been permitted to reduce the retention of a rational learning problem to a very low level, further interpolation of another rational learning problem has been found to produce a facilitating, rather than an inhibitory, effect upon relearning (5). This result points strongly to the importance of transfer factors in determining the influence of interpolated learning.
6. Greater retroactive inhibition has been reported in two studies (10, 26) when the transfer effect from original to interpolated learning is negative rather than positive, and this result has been indirectly supported by several experiments on the similarity factor in retroaction.
7. The evidence from recent studies (25, 26) which have involved direct measurement of both transfer and retroaction, indicates that positive transfer effects—or the changing relationship of positive to negative transfer factors—have very likely been of general, if sometimes unrecognized, importance in producing the usual reduction or elimination of retroaction in relearning as compared with recall scores.
8. The results are inconclusive concerning the relationship between cumulative transfer and cumulative retroaction.

PROBLEM AND PROCEDURE

The purpose of this experiment may be outlined as three-fold:

1. to determine the influence on retention, measured by relearning, of successive increments of interpolated training on highly similar learning problems
2. to determine the transfer effect of corresponding amounts of such cumulative training upon the learning of the original problem.
3. to compare the transfer curve thus obtained with the retroaction curve obtained from the same training inserted as interpolated learning, in order to gain factual information on the relationship between transfer of training and retroactive inhibition.

With respect to the first problem, if retroactive inhibition from learning similar material during the interval is the major determining condition of forgetting, then increasing amounts of forgetting should accompany progressive increments in the quantity of interpolated material of a similar nature. Under such circumstances the forgetting curve of the first problem would continue to approach the base line, or complete forgetting, as more and more similar problems were learned before the test for retention of the first problem. On the other hand, if there is a limit to the amount of retroactive inhibition that can be produced by the later learning of similar problems, then the forgetting curve will not continue its approach to the base line with increasing amounts of interpolation but a point will be reached after which additional amounts of the same kind of learning will fail to produce further retroactive inhibition in the memory of the original problem.

Whatever the results of the retroaction part of this experiment may be, they will presumably be a function of the relationship which exists between the interpolated and the original learning problems. The second part of the study has therefore been designed to check the transfer effects which are produced by corresponding amounts of the same cumulative training upon original learning. The effects of varying amounts of training upon retention, in the first case, and upon transfer, in the second, may then be directly compared.

Plan of Experiment

In the retroaction part of the experiment 120 white rats were given a large multiple-T water maze to learn to a criterion of one perfect trial, and were then divided into five Retroaction (R) groups, four experimental, or work, and one control, or rest. During the fifteen day interval between original learning and the relearning test on the first problem (maze A), varying numbers of short water maze patterns (B mazes) were interpolated. The number of the mazes used as interpolated tasks was 0, 1, 4, 8 and 12; these figures are attached to the Retroaction symbol R to indicate the work conditions of each group. Thus group R0 is the control, zero retroaction condition, and group R12 is the condition with twelve interpolated tasks, the maximum number used. Experimental conditions for the five R groups are outlined in Table 1.

Four additional groups of approximately twenty-five subjects each were em-

oyed in the Transfer (T) conditions. These animals were given training on the same short mazes which were used as the interpolated problems for the experimental animals in the R groups, the difference being that their B maze training preceded rather than followed their original learning of maze A. It was not necessary to provide a special group of animals for the control transfer condition (T0) since the combined original learning records of all R animals on maze A satisfied this requirement. Experimental conditions for the T groups are given in Table 2.

In order that units of interpolated learning activity be as nearly equal as possible for all experimental conditions, all B maze training was restricted to ten trials daily, regardless of degree of learning achieved. It should be emphasized

TABLE 1
*Plan of Retroaction (R) conditions**

GROUP	LEARNING	INTERPOLATED TRAINING	RELEARNING
R0	Maze A	None	Maze A
R1	Maze A	1 B maze	Maze A
R4	Maze A	4 B mazes	Maze A
R8	Maze A	8 B mazes	Maze A
R12	Maze A	12 B mazes	Maze A

* Fifteen day interval between learning and relearning; first B maze given thirteen days before relearning, others daily thereafter.

TABLE 2
*Plan of Transfer (T) conditions**

GROUP	PRELIMINARY TRAINING	LEARNING
T0	None	Maze A
T1	1 B maze	Maze A
T4	4 B mazes	Maze A
T8	8 B mazes	Maze A
T12	12 B mazes	Maze A

* First B maze given thirteen days before learning, others daily thereafter.

that for every two corresponding R and T groups (that is, each pair with the same number of B mazes) the daily training provided was made as similar as possible. Since all experimental groups started their training on the same day for each cycle of animals) all animals running at any one time had the same maze on that day, and each pair of corresponding R and T groups concluded their B maze training on the same pattern. The day for original learning of maze A by the T animals also coincided with that for relearning of maze A by the R animals. These details are presented in Table 4.

As a check upon the retroaction curve based on relearning tests on maze A it was decided to include also a retention test on the first interpolated maze (B1), which had been given to all groups except R0. This test, consisting of

ten trials massed practice, was administered on the day following the last learning of maze A. Table 3 illustrates the plan of this part of the experiment and indicates the manner in which the four transfer groups from the main part of the experiment were utilized as the B maze Retroaction (BR) groups. The control zero interpolation, condition is supplied by a new group, BR0 (*cf.* Table 4). The numbers again refer to number of interpolated tasks, but the learning of maze A is of necessity the last such task for all BR interpolated conditions.

TABLE 3
*Plan of B maze Retroaction (BR) conditions**

GROUP	LEARNING	INTERPOLATED TRAINING	RELEARNING
BR0	B1	None	B1
BR1 (T1)	B1	Maze A	B1
BR4 (T4)	B1	3 B mazes, Maze A	B1
BR8 (T8)	B1	7 B mazes, Maze A	B1
BR12 (T12)	B1	11 B mazes, Maze A	B1

* Fifteen day interval between learning and relearning; control, BR0, only group not derived from T groups; other derivations shown in parentheses.

TABLE 4
Plan of Experiment

N	GROUP	MAZES																
		Days of Experiment																
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
22	R0	A															A	B1
120*	T0*	A																
25	R1	A		B1													A	B1
26	T1			B1													A	B1
26	R4	A		B1	B2	B3	B4										A	B1
28	T4			B1	B2	B3	B4										A	B1
24	R8	A		B1	B2	B3	B4	B5	B6	B7	B8						A	B1
24	T8			B1	B2	B3	B4	B5	B6	B7	B8						A	B1
24	R12	A		B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12		A	B1
25	T12			B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12		A	B1
22	BR0			B1														B1

* T0 group composed of original maze A records from all R animals.

Subjects

The subjects for this experiment were 245 young white rats, obtained from a local animal dealer. They were brought into the laboratory at least one week in advance of their first day's learning session, at which time they were from forty to sixty days of age.

The distribution of subjects into groups was made so as to equate each condition in terms of original learning records. Equating of R groups was on the

basis of trials on first learning of maze A; equating of T groups (and condition BR0) was on the basis of errors made on the first B maze. That the differences between group averages were small and insignificant is indicated by the fact that the ratio of the largest difference to its sigma was, for the R groups 0.36, and for the T groups 1.04.

The animals were fed on Purina Dog Chow. Since hunger motivation was not used, food and water were available to them at all times. They were vigorous and in good health and continued to grow and gain in weight throughout the experimental period, in spite of the concentrated daily maze swimming required of certain groups.

The animals were evenly divided by sex, with most groups even or practically so in this respect (totals: 123 females, 122 males). They were run in six cycles, of approximately forty animals each. The total time for each cycle was seventeen days. New animals were thus being started on the average about every three weeks. It was planned to distribute the forty animals of each cycle more or less evenly over the ten groups, so as to avoid concentrating in any one group subjects of unusual quality, should there be a variation from cycle to cycle in the rats supplied by the dealer. So far as was possible this was done and ordinarily each group was represented by from three to five rats per cycle.

Apparatus: maze A

The apparatus used in this problem was a 14 unit multiple-T maze. It was kept filled with water to a depth of eight inches, at an approximate temperature of 65° F. The motivation was thus escape-from-water accomplished necessarily by swimming. At the end of the maze the animals climbed onto a wire mesh ladder leading directly to a dry goal box with warm air circulating through it from electric heaters.

A diagram of the multiple-T maze has been presented elsewhere (8). In this problem it was thought desirable to utilize six gates or doors, placed at strategic junctions in the maze, and lowered by the experimenter after the animal had passed through so as to prevent excessive retracing in those parts of the maze already successfully traversed.

Apparatus: B mazes

Since the maximum number of interpolated tasks was twelve, there had to be twelve separate B mazes. These were obtained from the complete maze A pattern by using certain sections to make up shorter maze problems, providing start and finish points in blind alleys of maze A and blocking off those runways not needed. The following cautions were among those observed in the forming of the twelve B mazes:

1. Each maze had to be different from each other.
2. Each maze had to be constructed of a total of from nine to twelve separate units, including true pathway as well as blind alley runways. (There are twenty-nine such units in maze A.)
3. Each maze had to have one door, placed near the middle of the pattern, so as to prevent retracing from that point.

Obviously considerable similarity between the B mazes and maze A, as well as the maze B patterns themselves, could not be avoided. This was, however, not considered undesirable, since it has been sufficiently demonstrated that retroactive inhibition generally increases with greater similarity between original and interpolated materials and the object of the interpolated training was to produce as much retroaction as possible.

A typical B maze is diagrammed in Fig. 1. For the purposes of this report it will be convenient to refer to B mazes as B1 through B12, in accordance with their serial order of interpolation. That is, B1 will refer to every maze which was interpolated first in any of the six cycles of the experiment, regardless of its particular pattern. Similarly B2 will refer to every maze that was used on the second day of interpolated training, etc.

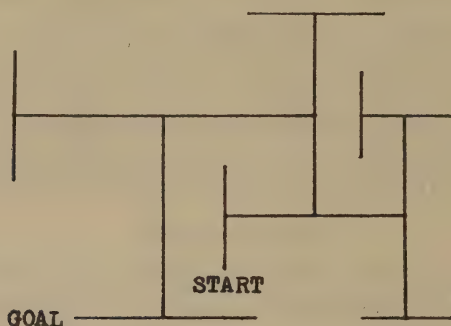


FIG. 1. A TYPICAL B MAZE

Procedure: maze A

The usual procedure for the running of rats on maze A was to start from twelve to sixteen animals at one time, putting them through in rotation. Training was by this massed practice method and was continued for each rat until it had met the criterion of learning of one perfect trial.

Detailed individual record sheets were kept for number of trials, time per trial, and errors per trial. Time was taken from the moment the animal entered the maze until it reached the wire mesh ladder at the end. Each error was marked on the record sheet according to its location in the maze. Errors on maze A were of three types, illustrated in Fig. 2 and explained as follows:

1. True pathway errors, one counted for each unit of the true pathway entered in the wrong direction. These are abbreviated T.
2. Blind pathway errors in the stems of the blind alleys. These are abbreviated B.
3. Blind end errors in either of the two ends of each blind alley. These are abbreviated E.

Procedure: B mazes

The usual procedure for running rats in the B mazes was as similar as possible to that used for maze A. The major difference was that training was not to any

set criterion of mastery but was rather for a constant number of trials. Ten trials on each maze were given, under the massed practice method, regardless of the degree of learning acquired. It was believed that this would be the easiest and very likely the best of the three criteria (trials, time and errors) to equate.

Individual records were kept under the same general conditions as for maze A. Errors were recorded and counted as in maze A but were not analyzed into the three types.

The B mazes were interpolated in a counterbalanced order for each cycle of animals, in order to eliminate so far as possible incidental variations in difficulty, which might have proved troublesome in spite of attempted objective equality of the patterns, had the problems been presented in the same sequence for each new cycle of subjects. It is therefore considered justifiable to disregard, for the group average purposes of this report, the individual identities of B mazes.

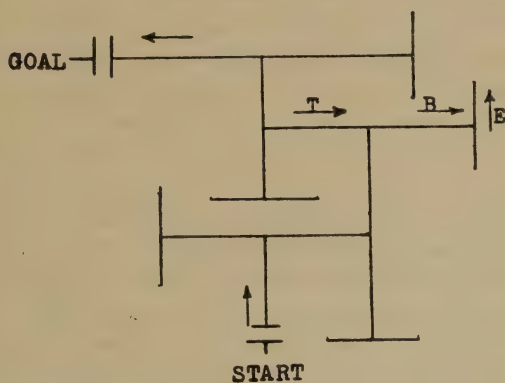


FIG. 2. A SECTION OF MAZE A, SHOWING SEVERAL UNITS OF TRUE AND BLIND PATHWAY AND ILLUSTRATING THE THREE TYPES OF ERRORS

There are two types of B mazes, namely those that proceed in a forward direction with respect to the true pathway of maze A (that is, their start is in a blind alley nearer the start of maze A than is their goal) and those that proceed in a backwards direction. It was arbitrarily decided to have the interpolated training of each group end with a backwards type maze, since there were only six such terminal positions and in case there was any difference in difficulty between the two types of mazes it would be necessary for purposes of strict control to have all rats conclude their interpolated training with the same type, and some rats conclude with each of the six different backwards mazes. Backwards mazes therefore were interpolated in positions 1, 4, 6, 8, 10 and 12.

RESULTS

1. Cumulative transfer in the learning of twelve successive mazes

Before the influence of cumulative transfer upon retroactive inhibition can be deduced from the main results of the experiment it is necessary to demonstrate that cumulative transfer actually did occur. Evidence will therefore be presented

to indicate, first, the character and extent of improvement in maze learning that results from previous training on from one to eleven similar mazes. These results, it may also be remarked, are not without interest in their own right inasmuch as the literature has no more than two or three contributions on the subject.⁷

The various learning curves to be presented in this section are all based upon the twenty-five subjects of group T12. These animals had ten trials daily on a different B maze for each of twelve consecutive days. All animals learned the same twelve mazes but not in the same sequence; the order was counterbalanced for the purpose of controlling small differences in maze pattern and difficulty (*cf.* footnote 8, p. 15). Figs. 3 and 4 show the learning curves that were obtained from the records of the first, fourth, eighth and twelfth mazes. The main point of interest in these curves is that, so far as gross measures of total time and errors are concerned, improvement from trial to trial is clearly continuous throughout the ten trials only on the first maze learned and is thereafter confined in increasing degree to the first half of the curve. While small amounts of improvement are apparent for the fourth and eighth and even for the twelfth maze through the first six or seven trials, it is obvious that by far the larger part of the decrement in both errors and time has occurred within the first three or four trials.

These curves are of interest in showing the progressive changes that take place within the learning process with added increments of practice but they are not especially well fitted to demonstrate the occurrence or non-occurrence of cumulative transfer in terms of total scores for each day's activity. The evidence for cumulative transfer in this type of maze learning is presented in Figs. 5 through 8. In each of these curves the scores on the first and second B mazes are plotted separately but the scores on succeeding pairs are combined, primarily in order to

⁷ Wiltbank's (35) study has been mentioned earlier (p. 5). While he did not think he had demonstrated cumulative transfer in learning by white rats of five consecutive mazes, Woodworth (36, p. 199) later reworked the data and concluded from group averages that there had been some transfer through the first four mazes. Ward (32) found considerable improvement in the first few lists of nonsense syllables learned by subjects who had already had four preliminary lists to learn. The improvement in terms of trials required for complete mastery seemed to continue at a very decelerated rate through the sixteen lists learned, but transfer effects for partial mastery scores appeared to show little change after the first nine or ten lists.

An interesting case of what may well have been cumulative transfer of a negative character has been supplied by Twining (30), who gave his subjects ten trials on from one to five lists of nonsense syllables interpolated within a thirty-minute period following complete mastery of an original list. Although the experimenter does not report mean scores for each list separately, he does present the average scores for each group. These average scores for *all* the lists learned by each group show small but uniform differences in favor of the subjects with less interpolated learning, mean number of correct anticipations being 32.6, 30.8, 30.31, 28.8, and 27.04. The slight but consistent interference indicated in this experiment may presumably have been due to the extreme massing of incompletely learned materials, since negative transfer effects have been shown to be greatest under conditions of short time intervals (7) and low degree or amount of original learning (27).

smooth the curve by eliminating some of the chance variations from errors of measurement.⁸

Per cents of transfer in terms of total errors and total time for the ten trials are given in Fig. 5. Inspection of the two curves reveals that while the transfer effect is large and continuous for the first five or six B mazes it appears to have leveled off for the remainder of the twelve mazes, with a suggestion of a further



FIG. 3. THE CUMULATIVE TRANSFER EFFECT, AS SHOWN BY THE AVERAGE TIME IN SECONDS PER TRIAL FOR T12 ANIMALS ON MAZES B1, B4, B8 AND B12

increase at the end. The curves of Fig. 6, which represent the cumulative transfer effects in terms of time and error scores on the first trial of each day's learning,

⁸ It may also be recalled that there are two types of B mazes, since the true pathways proceed either in a forward or a backward order along the true pathway of maze A. In order to have all rats conclude their training with the same type of maze, the six that run in a backward order were arbitrarily counter-balanced for each cycle in positions 1, 4, 6, 8, 10 and 12 (*cf.* p. 13). Although there was apparently no consistent variation in difficulty between these two types, the mere fact of a difference in type would provide further justification for combining successive pairs.

show a similar trend. This result might be interpreted as an indication that the shape of the transfer curves of Fig. 5 may be entirely a function of the improvement in first trial scores. That this is not true, however, is suggested by the curves of Figs. 7 and 8, which compare, for time and errors respectively, the cumulative transfer effect in each half of the ten trials. These curves indicate that the facilitative effect is general and is not confined to the first few trials. It is obvious that the first trial scores, being larger than those of any succeeding trial,

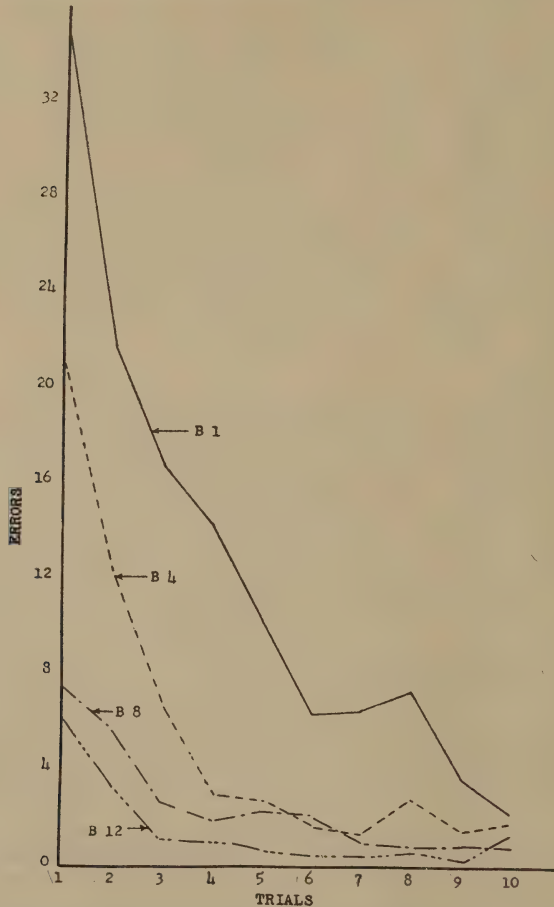


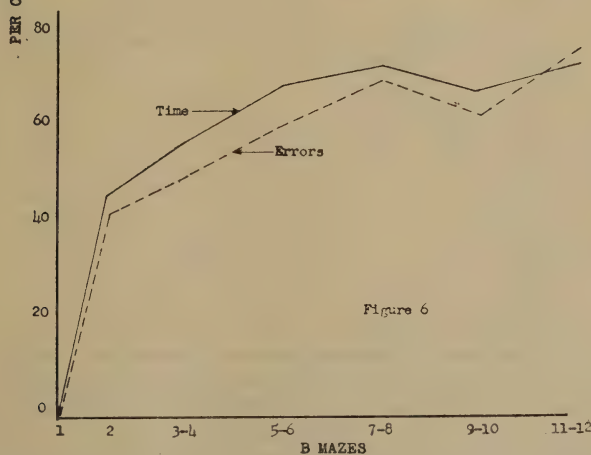
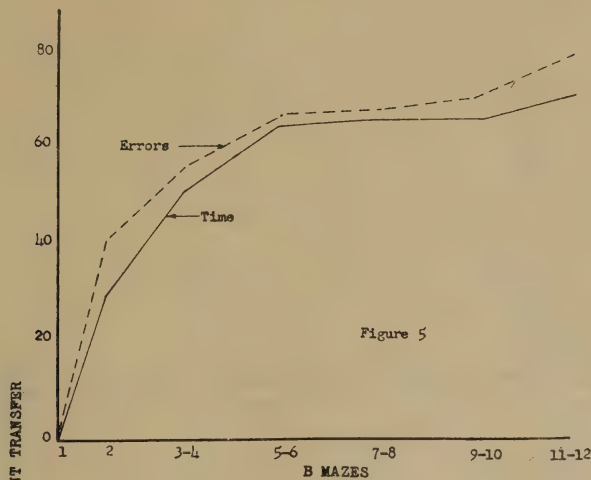
FIG. 4. THE CUMULATIVE TRANSFER EFFECT, AS SHOWN BY THE AVERAGE NUMBER OF ERRORS MADE PER TRIAL BY T12 ANIMALS ON MAZES B1, B4, B8 AND B12

do contribute a larger *absolute* amount to the total transfer curves of Fig. 5. It is equally obvious, however, from Figs. 7 and 8, that the shape of the transfer curves is not at all affected when the early trials are excluded.

In all the curves of Figs. 5 through 8 there is evident a marked leveling off of the cumulative transfer influence at about the fifth or sixth maze.⁹ Taken at

⁹ Comparison of Figs. 7 and 8 suggests that the flattening of the transfer curve is less pronounced for errors than for time scores, but the deflection of the former curves is still sufficient to justify the generalization.

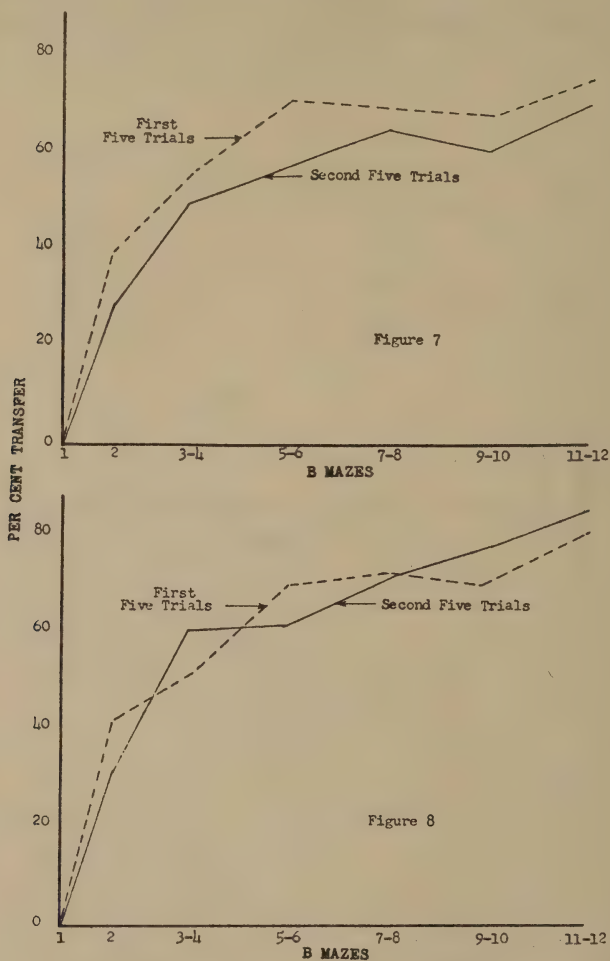
face value, these results suggest that improvement in time and error scores in learning several mazes is progressive until the fifth or sixth such maze has been learned but that additional increments of training from then on do not have a very great facilitating influence. Such a conclusion is not tenable, however, in view of the curves of Figs. 9 through 11. These are not based on gross time and error scores but are designed to illustrate the influence of practice measured



FIGS. 5 AND 6. CUMULATIVE TRANSFER IN TOTAL TIME AND TOTAL ERRORS (FIG. 5) AND IN FIRST TRIAL TIME AND FIRST TRIAL ERRORS (FIG. 6) ON B MAZES (T12 ANIMALS)

by a different criterion—the number of errorless trials achieved at the various stages of training. Fig. 9 presents the percentage of trials that are perfect in each set of five trials. While the percentage of errorless trials is at all stages of practice considerably higher in the second half of the ten trials, the shape of the two curves is essentially the same and neither curve gives any suggestion of the leveling off that is apparent when total time and error scores are considered.

The 70 per cent reached by these animals on maze B12 means that on the average 3.5 of every five trials are errorless in the last half of the ten trials. It is probable, moreover, from the shape of the curve that this figure would have become even larger had practice been continued.



FIGS. 7 AND 8. CUMULATIVE TRANSFER IN TIME (FIG. 7) AND IN ERRORS (FIG. 8) ON FIRST ON FIRST FIVE TRIALS AND SECOND FIVE TRIALS ON B MAZES (T12 ANIMALS)

The tendencies apparent in Fig. 9 are better illustrated, perhaps, in the two curves of Fig. 10. Here is represented the per cent of T12 animals that have achieved, at the various training stages, a minimum of three or of five errorless trials out of the day's ten. Again evident are the failure of any leveling off tendency (suggestion of a slight upturn, if anything) and the linear rather than negatively accelerated shape of the transfer curves. The rise of the lower curve to a point above the 75 level means that by the time the last two mazes were

learned three out of every four animals were running the maze with at least five errorless trials out of the total ten.

Fig. 11 gives the actual frequency distribution for the same data, revealing that the modal number of perfect trials shifts from zero to between four and five, then to six and finally to eight, and again showing that the mazes are progressively better learned as the amount of maze experience prior to the test is increased.¹⁰

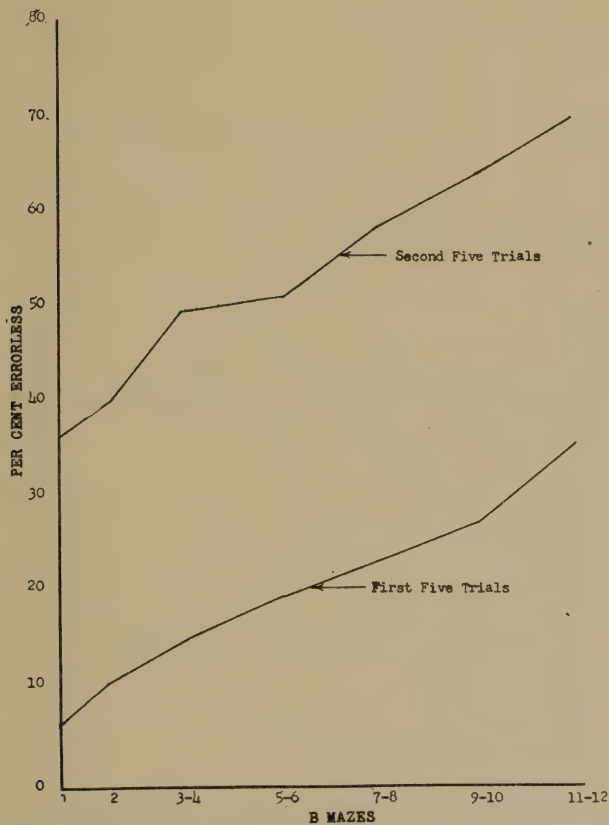


FIG. 9. PER CENT OF FIRST FIVE TRIALS AND SECOND FIVE TRIALS THAT IS ERRORLESS ON THE VARIOUS B MAZES (T12 ANIMALS)

Learning to a criterion of mastery has not thus far been invoked in this discussion since training on the B mazes was not to mastery but was rather for an

¹⁰ The explanation of why a sizable proportion of the animals should fail to achieve even one errorless trial on the twelfth B maze, will be readily apparent upon consideration of the following point. Examination of the learning records of such animals on maze B12 has revealed the persistence in each case of one or two errors which were seemingly learned as a part of the total maze habit. It should also be observed that on the twelfth maze there are no cases of merely one, two or three perfect trials, indicating that at this stage of training the pattern is learned earlier, and is better retained once it has been learned.

arbitrary number of trials each day. However, if the median number of trials required for the first of second errorless trial is considered,¹¹ the evidence is again for continued cumulative transfer effects through the twelfth maze. The median numbers of trials required for learning to a criterion of one perfect trial were, for the first, fourth, eighth and twelfth mazes, 9, 5, 5 and 3, and the median

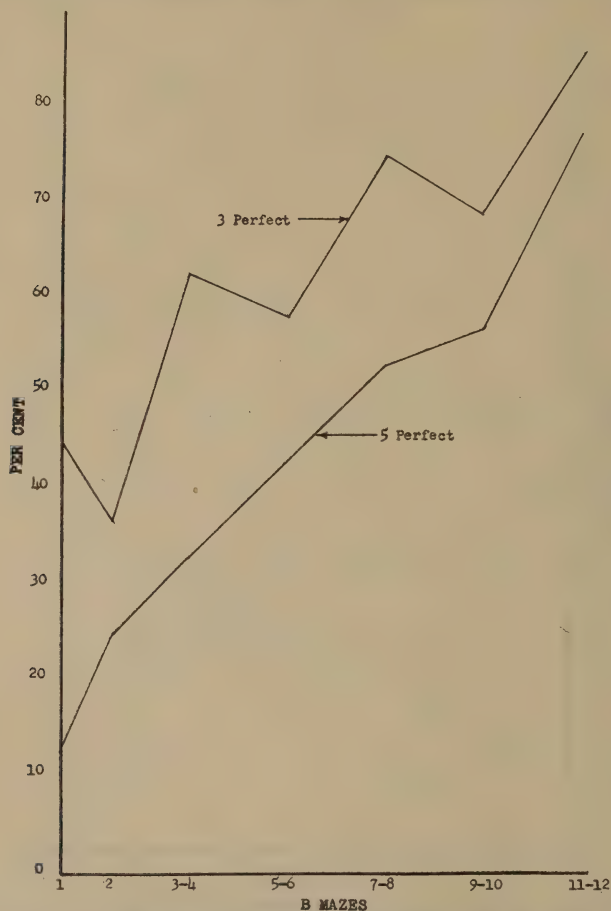


FIG. 10. PER CENT OF T12 ANIMALS WITH AT LEAST THREE AND AT LEAST FIVE ERRORLESS TRIALS OF EVERY TEN, ON THE VARIOUS B MAZES

numbers of errors made on those trials were 99, 40, 18 and 9. The median numbers of trials required for learning to the second perfect trial were, in the same order, 10, 7, 6 and 4. The number of animals learning to a criterion of

¹¹ The median is used here rather than the more stable mean since there was always a small minority which did not achieve at least one perfect trial within the ten. It is obvious, therefore, that the mean cannot be employed, but so long as more than half the animals did attain the criterion the median, or middle score, can be applied.

three perfect trials was too small on the earlier mazes to justify further comparisons of this sort.

The results of this section seem sufficiently clearcut to permit of certain generalizations. The data leave little doubt that, in terms of total number of perfect trials, or percentages of animals achieving arbitrary levels of learning, or median numbers of trials and errors required to learn to definite criteria of

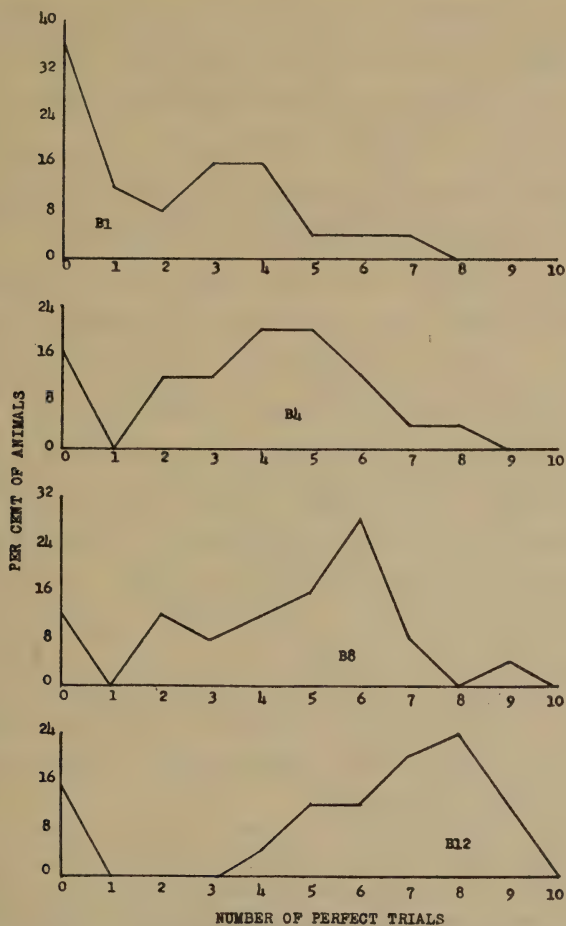


FIG. 11. PER CENT OF ANIMALS WITH VARYING NUMBERS OF PERFECT TRIALS ON CERTAIN OF THE B MAZES (T12 ANIMALS)

mastery, transfer effects in this experiment have continued to act cumulatively through twelve successive similar maze problems. On the other hand, when gross error and time scores are considered, the cumulative effect is clearly apparent only through the fifth or sixth maze, although there is a slight suggestion of further facilitation at the eleventh and twelfth mazes. It would seem to be a safe conclusion that the transfer has been cumulative throughout the whole

series of mazes, since animals which have had the benefit of eleven mazes (110 trials) produce learning records clearly superior in at least three important respects to those which they had made earlier.¹²

2. *Cumulative transfer and retroactive inhibition in the relearning of a difficult maze problem, learned to mastery*

Evidence for the existence of cumulative transfer factors within the preliminary learning of B mazes having been presented in the preceding section, it will now be possible to examine the main results of the experiment to determine: (1) the extent to which retroactive inhibition is cumulative and (2) the extent to which it is related to cumulative transfer.

a. *Retroactive inhibition: maze A.* The three curves of Fig. 12 may first be considered. They represent the percentage of animals in each of the R groups which have shown a savings on the relearning of maze A after varying amounts of interpolated training on the B mazes. It is readily apparent that, in terms of this criterion, the greatest retroactive effect (that is, the least number of animals showing savings) occurs somewhere in the middle of the range of interpolated learning. In two of the curves (trials and errors) R8 animals have the poorest records and in the third (time) they show only a slight advantage over R4 animals. On the other hand, it may be noted that groups R0 and R1 are superior to group R12 only on the basis of time scores and that even here the difference between R0 and R12 is negligible, being less than three per cent (of a total range of twenty-five per cent). In the other two comparisons as many R12 animals show savings as do R0 and R1 animals. All three groups, moreover, are clearly superior to R4 (except for errors) and R8.

These results do not take into account quantitative differences and are not amenable to ordinary statistical treatment. Nevertheless, as supplements to the more refined data that follow, they do have a certain value; and it is fair to interpret them as suggesting that the retroactive effect of B maze training is cumulative to a peak approximately between four and eight interpolated mazes and that after this point has been passed successive increments of training are beneficial rather than detrimental.

Before presenting the data which require statistical treatment some comment concerning technical and tabular arrangements is in order. Percentages of retroactive inhibition are based upon the relearning scores of the control or rest group, R0, and have been computed according to the standard formula: $(\text{Rest} - \text{Work}/\text{Rest}) \times 100$. Percentages of savings are based for each group upon its own original learning records and have been computed according to the formula: $(\text{Learning} - \text{Relearning}/\text{Learning}) \times 100$. Along with these percentages the

¹² The interpolated learning records of animals in group R12 have also been scored extensively and reveal the same general tendencies. It is of some interest to note, in comparing the two groups, that the transfer influence of the original learning of maze A, while producing a relatively large and significant advantage for group R12 on maze B1, had disappeared by the next B maze in terms of errors and by the fifth in terms of time, as indicated by an actual shift in superiority (that is, advantage to T12). The difference in time was still large on the second maze, but was insignificant on the third and fourth.

basic data from which they are obtained are presented with sigmas of the means in tabular form as they are required. Critical ratios for important comparisons are mentioned in the text. There is no correlation factor involved in the computations of the standard errors of the differences.

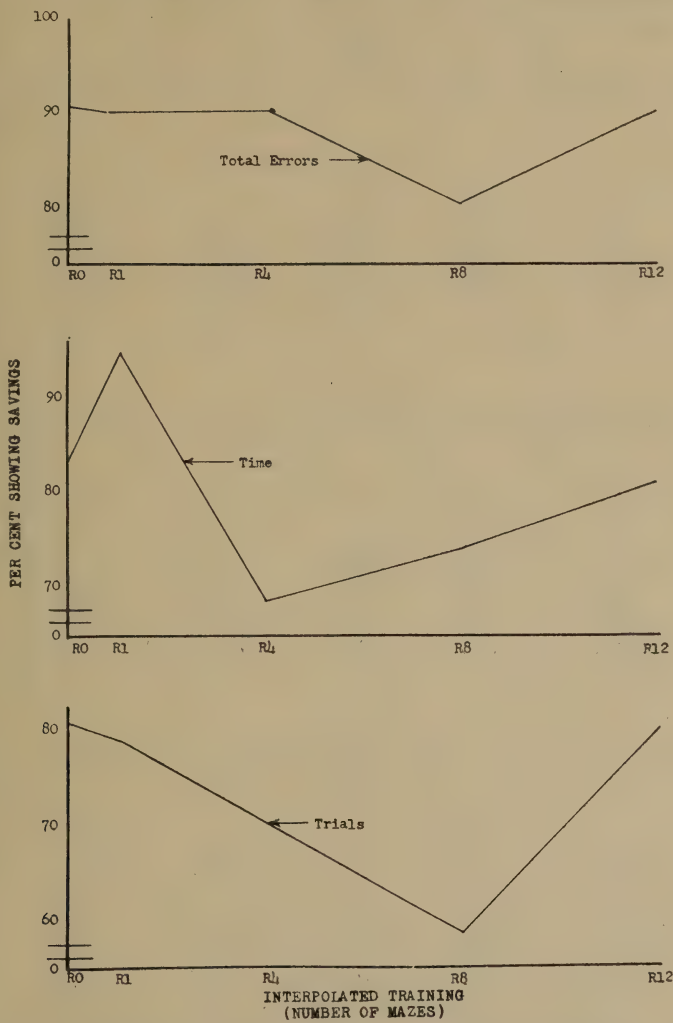


FIG. 12. PER CENT OF ANIMALS SHOWING SAVINGS IN RELEARNING MAZE A AFTER VARYING AMOUNTS OF INTERPOLATED TRAINING ON B MAZES

Percentages of retroactive inhibition, from the data of Tables 5 through 7, are given graphically in Fig. 13 for all three criteria (trials, time and errors scores). Inspection of these curves immediately indicates that the conclusions based upon the corresponding curves of Fig. 12 (percentages of animals showing savings) are confirmed by two of the three measures. In terms of trials to relearn and total time scores the peak of retroaction again occurs about the middle of the

range of interpolated learning, with groups R4 and R8 definitely inferior to the others. Compared to the relationship found in Fig. 12, the beneficial effect from increased interpolation is less pronounced in the R12 group, which for both of these criteria is somewhat above the level of R1, but the decrease from the two medium levels of interpolated learning is still quite marked.

TABLE 5

Means and standard errors for Retroaction groups in learning of maze A

GROUP	TRIALS		TIME (SEC.)		ERRORS	
	M	σM	M	σM	M	σM
R0	21.33	2.46	1806.67	211.19	236.48	29.04
R1	21.76	2.54	1995.20	255.16	222.16	21.16
R4	22.38	2.91	1705.96	249.78	198.19	22.17
R8	20.96	2.66	1873.42	280.56	193.29	26.21
R12	21.46	2.15	1613.89	157.75	218.38	23.79

TABLE 6

Means and standard errors for Retroaction groups in relearning of maze A

GROUP	TRIALS		TIME (SEC.)		ERRORS	
	M	σM	M	σM	M	σM
R0	8.24	1.60	601.43	152.40	53.05	9.80
R1	9.84	1.44	648.12	84.59	71.08	11.15
R4	14.81	2.68	922.73	185.97	70.65	8.70
R8	14.29	2.63	1046.58	170.97	75.38	9.94
R12	10.96	2.08	750.50	122.46	75.83	13.87

TABLE 7

Per cent savings and per cent retroactive inhibition for Retroaction groups in relearning of maze A

GROUP	PER CENT SAVINGS			PER CENT R.I.		
	Trials	Time	Errors	Trials	Time	Errors
R0	61.37	66.70	77.57			
R1	54.78	67.52	68.02	19.41	7.76	33.99
R4	33.82	45.91	64.35	79.73	50.24	33.18
R8	31.82	44.14	61.00	73.42	74.02	42.09
R12	48.93	53.50	65.28	33.01	24.78	42.94

Disregarding for the moment the total errors measure, we may examine the critical ratios of these differences.¹³ That the retroactive effect is very likely a

¹³ The differences are, of course, those between the means of the relearning scores. The deviations between group averages in original learning were small and insignificant, as is indicated by the following critical ratios for the *largest* such differences (cf. Table 5): trials, 0.36; time, 1.23; and errors, 1.13.

real one is indicated by the fact that the differences between R0 and the two medium interpolation groups, R4 and R8, are each about twice the size of their sigma for trials (2.11 and 1.96, respectively); the corresponding ratios for time are as great for R8 (1.94) but insignificant for R4 (1.31). The chances are roughly 98 out of 100 that the retroactive effect on the R8 animals was genuine and cannot be attributed to chance variations; and they are just as high that the retroaction in the R4 group was real in terms of trials.

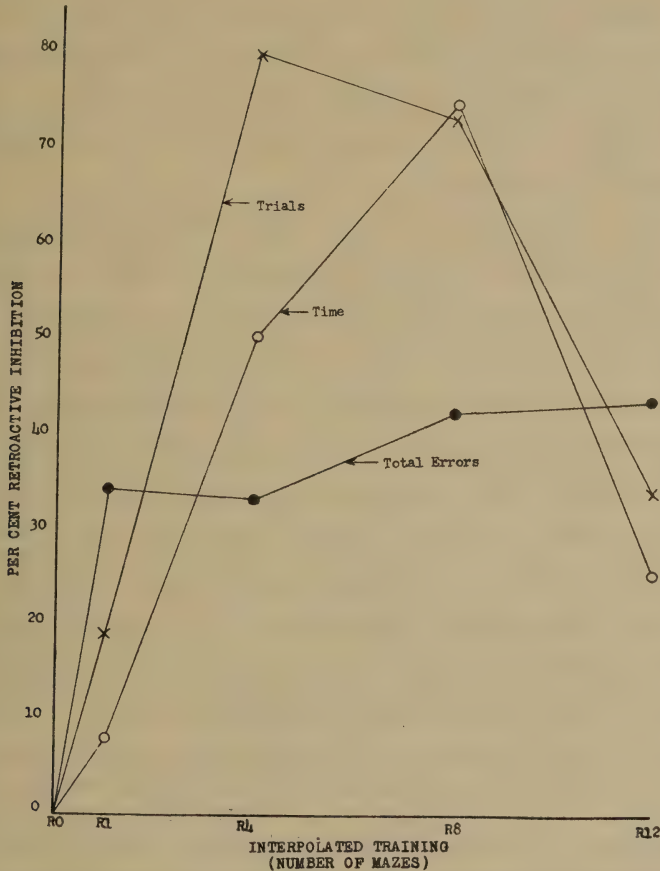


FIG. 13. PER CENT OF RETROACTIVE INHIBITION IN RELEARNING OF MAZE A AFTER VARYING AMOUNTS OF INTERPOLATED TRAINING ON B MAZES

The decrease in retroaction found in the R12 animals cannot be regarded as very reliable statistically since the differences between R12 and R8 means are about the size of their sigmas; however, the same may be said of the differences between the R12 and R0 groups, since these are also no larger than their sigmas. Solely on the basis of statistical reliability we may then conclude that while a fairly reliable retroactive influence has been demonstrated for the medium range of interpolation it has not been demonstrated for the high end of the scale.

It would seem better, however, to conclude that for trials and time measures the decrease in retroaction with increasing amounts of interpolated learning is probably a genuine one, although the conditions of the experiment ($N = 25$ on the average) were not able to make it large enough for statistical reliability.

With respect to the criterion of total errors in Fig. 13 the picture is considerably different. It is apparent that the retroactive effect has practically leveled off after one interpolated maze, a result that is in direct contradiction to the evidence of the other two criteria.¹⁴ The peak of the retroactive effect is at the high end of the interpolation range; the decrease that was found for trials and time is not even suggested. Moreover, the largest difference is that between R0 and R8 and it can scarcely be considered very reliable, with a C.R. of 1.60. The difference between R0 and R12 is even less significant, being no more than 1.34 times its sigma. The corresponding differences for groups R1 and R4 are of approximately the same order.

Interpretation of the errors score is facilitated by breaking the gross totals down into their component error types. These, as shown in Fig. 2 (p. 13), are retrace errors in the true pathway (designated T), blind alley entrance errors (B), and blind alley end errors, in the end sections of the blind alleys (E). Fig. 14 represents the retroaction percentages for each type of error, from the data of Tables 8 through 10.¹⁵ The first two curves, those for T and B errors, show the progressive increase in retroaction with increasing amounts of interpolation, but apparently level off at R8 and R12. The slight final decrease in B errors is wholly insignificant (C. R. = 0.35), as is the slight final increase in T errors (C. R. = 0.23). That reliable amounts of retroaction have been produced after eight and twelve interpolated mazes is indicated by the critical ratios between R0 and the remaining groups: for T errors, 1.31, 1.13, 2.39, and 1.91 respectively, and for B errors, 1.39, 1.88, 2.55, and 2.40. The chances that the retroactive effect produced after eight and twelve interpolated mazes is a significant one are about 99 out of 100. The curve for E errors exhibits a wholly different trend, dropping below the retroaction base line for the high end of the interpolation scale after a slight rise for R1 and R4 conditions. The latter differences are, of course, insignificant; but there is some reason for believing that the facilitative effect with large amounts of interpolated learning may be statistically reliable. While the critical ratios between R0 and R8 and R12 are too low for significance, that between R1 (slight inhibitory effect) and R8 (considerable facilitation) is 2.02, making the probability of a true difference roughly 98 out of 100.

Before leaving the error analysis one more measure may be introduced. If the number of E errors that are made for every B error made (that is, the number of end entrances made for every stem error) is computed, simply by dividing the

¹⁴ The extent of the leveling off of retroaction at R1 is demonstrated by a comparison of the critical ratios between that group and the next two: these are, for errors, 0.03 and 0.39, and for the trials and time, 1.63 and 1.49, and 1.34 and 2.09, respectively.

¹⁵ Critical ratios for the *largest* differences between original learning means are all insignificant (type T: 1.47; type B: 0.87; type E: 1.48; and the E/B measure: 1.04).

E total by the B total, the data of Table 11 appear, revealing a progressive facilitating effect through condition R8, where an inversion of doubtful significance occurs. There seems to be little question of the statistical reliability of this trend. The differences between group R0 and groups R8 and R12 have critical ratios of 4.15 and 3.22 respectively; those between group R1 and groups R8

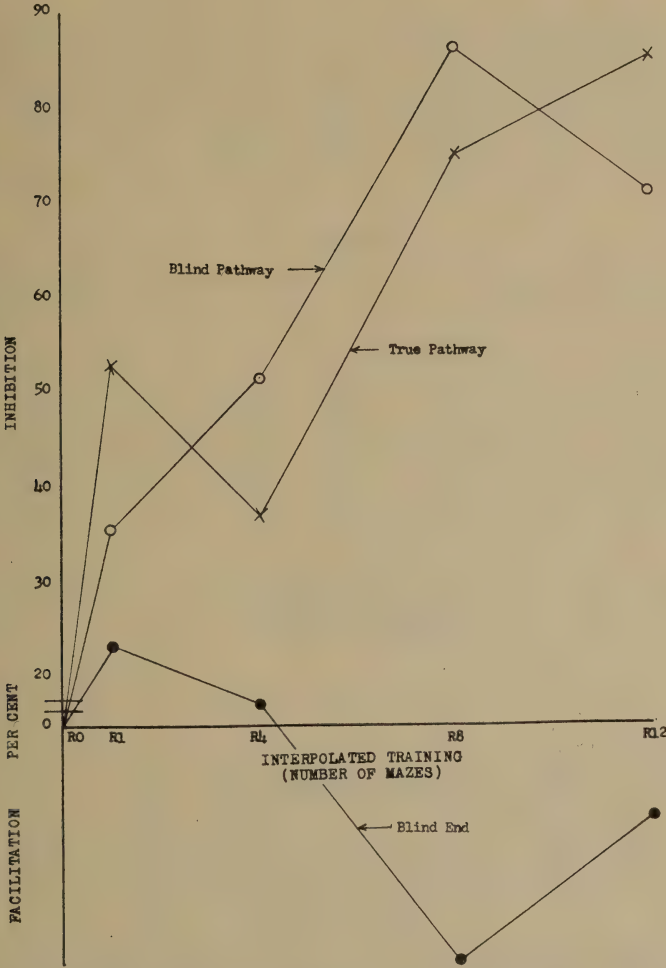


FIG. 14. PER CENT OF RETROACTIVE INHIBITION OR FACILITATION FOR THREE TYPES OF ERRORS IN RELEARNING OF MAZE A AFTER VARYING AMOUNTS OF INTERPOLATED TRAINING ON B MAZES

and R12 have critical ratios of 5.81 and 4.49. The inversion at R12 is represented by a fairly high ratio of 1.74 but in view of the relative size of the other ratios this cannot be given as much weight, on logical grounds, as might otherwise be the case. These figures mean, of course, that as quantity of interpolated training on B mazes increases there is a striking decrease, on the relearning of

maze A, in the tendency to continue into the ends of a blind alley after the stem has been entered, or a return in the stem towards the ends has been started.

TABLE 8

Means and standard errors in types of errors for Retroaction groups in learning of maze A

GROUP	T		B		E		E/B	
	M	σM	M	σM	M	σM	M	σM
R0	30.76	4.47	98.00	13.16	107.71	12.48	1.10	0.128
R1	27.72	3.62	95.04	10.01	99.76	9.39	1.05	0.055
R4	22.12	3.80	85.65	10.12	90.42	9.69	1.06	0.056
R8	27.33	4.64	83.13	10.97	82.83	11.38	1.00	0.075
R12	26.29	4.28	89.08	9.19	103.42	12.04	1.11	0.029

TABLE 9

Means and standard errors in types of errors for Retroaction groups in relearning of maze A

GROUP	T		B		E		E/B	
	M	σM	M	σM	M	σM	M	σM
R0	8.14	1.97	24.67	4.65	20.24	4.15	0.82	0.112
R1	12.48	2.67	33.60	4.31	25.00	4.33	0.74	0.053
R4	11.15	1.80	37.38	4.89	22.12	3.33	0.59	0.078
R8	14.25	1.64	46.00	6.95	15.13	2.29	0.31	0.052
R12	15.08	3.17	42.50	7.99	18.25	3.38	0.43	0.046

TABLE 10

Per cent savings and per cent retroactive inhibition in types of errors for Retroaction groups in relearning of maze A

GROUP	PER CENT SAVINGS				PER CENT R.I.			
	T	B	E	E/B	T	B	E	E/B
R0	73.53	74.82	81.21	25.45				
R1	54.98	64.65	74.94	29.52	53.32	36.20	23.52	-9.76
R4	49.60	56.36	75.54	44.34	36.98	51.52	9.29	-28.05
R8	47.86	44.66	81.73	69.00	75.06	86.46	-25.25	-62.20
R12	42.64	52.59	82.35	61.26	85.27	72.27	-9.83	-47.56

TABLE 11

Mean number of blind alley end (E) errors made per blind pathway (B) error for Retroaction groups in relearning of maze A

	R0	R1	R4	R8	R12
E/B.....	0.82	0.74	0.59	0.31	0.43
σM	0.112	0.053	0.078	0.052	0.046

Thus while on the average eight E errors were made for every ten B errors, in the R0 group, only three were made by the R8 animals and four by the R12 animals.

Apparently the interpolated training has been a definite hindrance in increasing the number of blind alley stem entrances but has been of considerable help in reducing the extent of such entrances.

The results of this section may be construed as indicating that the maximum retroactive effect from interpolated training generally occurs well in advance of the maximum amount of interpolation; that the retroactive inhibition levels off, at least, and probably actually decreases, as quantity of interpolated material is increased to the maximum used in the experiment; that when total error scores are broken down by types, not inhibition but facilitation occurs for one type (blind end entrances) in the same animals which are showing the strongest retroactive effects for the other types; and that, finally, there is no inhibition at all

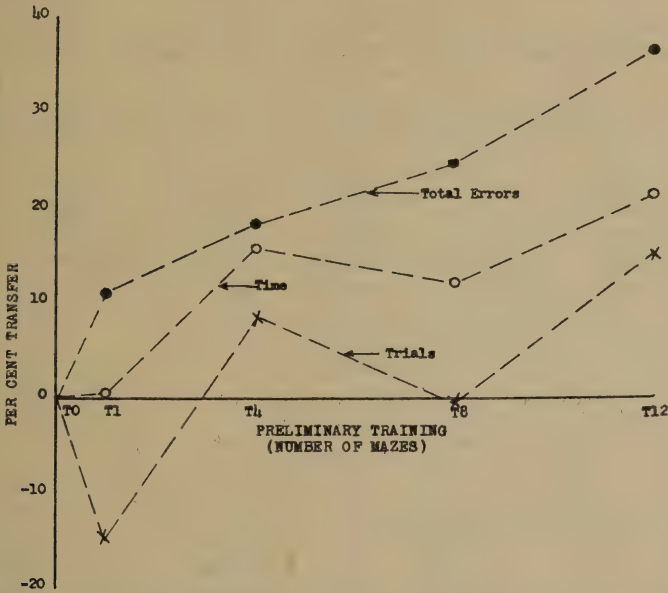


FIG. 15. PER CENT TRANSFER IN LEARNING OF MAZE A AFTER VARYING AMOUNTS OF PRELIMINARY TRAINING ON B MAZES

but a consistently progressive decrease, roughly proportional in amount to the quantity of interpolated training, in the tendency to explore the whole blind alley once a start in that direction has been made.

Further inferences from these results will be withheld until after presentation of the corresponding transfer data.

b. Cumulative transfer: maze A. The transfer curves for learning of maze A after varying amounts of training on the B mazes are shown in Fig. 15 in percentages for the three criteria of trials, time and errors. The strong negative acceleration of the transfer curves of Fig. 5 is obviously lacking, even in the only curve (that for total errors) in which the slope is at all regular. Instead, the positive transfer is weak and irregular for the first eight B mazes, with the exception of the total errors measure, and slight negative transfer is found in trials

after one B maze. It is clear that training on the B mazes is far more beneficial in the learning of another B maze than it is in the learning of maze A. Nevertheless, there is apparent in each curve at least a suggestion that the influence of the training has begun to take effect after twelve days of learning, for the best records by all criteria are achieved by the T12 animals. The difference between T0 and T12 is insignificant for the criterion of trials to mastery (C.R. of 1.18), but is fairly reliable in the case of both time (C.R. of 1.94) and total errors (C.R. of 3.11). The chances of a true difference are approximately 98 and 99.9 out of 100, in terms of time and errors respectively. It may also be noted that the slight inversion from T4 to T8 in the trials and time curves is wholly insignificant (C.R.'s of 0.42 and 0.21) and may be attributed to chance variations.

TABLE 12
Means and standard errors for Transfer groups in learning of maze A

GROUP	TRIALS		TIME		ERRORS	
	M	σM	M	σM	M	σM
T0	21.60	1.16	1790.63	101.51	212.94	10.81
T1	24.88	2.91	1790.77	251.95	190.27	20.52
T4	19.82	3.50	1509.64	246.95	174.00	30.67
T8	21.63	2.50	1574.13	178.10	164.58	17.41
T12	18.32	2.52	1404.00	171.64	134.40	18.30

TABLE 13
Per cent transfer for Transfer groups in learning of maze A

GROUP	TRIALS	TIME	ERRORS
T0			
T1	-15.19	-0.01	10.65
T4	8.24	15.69	18.29
T8	-0.14	12.09	24.59
T12	15.19	21.59	36.88

When type of error is considered, the reason for the strong transfer effect in total error scores at once becomes apparent. Fig. 16 represents the average number of each type of error made by the T groups after varying amounts of B maze experience.¹⁶ It is evident that the decline in total errors is a function of the regular decline of only one type of error, the blind end, and that the true pathway and the blind pathway kinds are relatively unaffected by increasing amounts of B maze training. The differences for the two latter types are small and insignificant, the largest (type B, between T0 and T12) being only 1.23 times its sigma. There is no doubt, however, of the statistical reliability of the decrement in type E errors; the critical ratios of the differences between the con-

¹⁶ The data are presented here in raw scores, but percentage scores are plotted in Figs. 18 and 19 (p. 34).

rol (T0) group and the remaining groups are, in order of increasing amounts of maze training, 3.65, 2.53, 6.89, and 9.87. Even the difference between the two groups with the most training, T8 and T12, is nearly twice its sigma (C.R. of

TABLE 14

Means and standard errors in types of errors for Transfer groups in learning of maze A

GROUP	T		B		E		E/B	
	M	σM	M	σM	M	σM	M	σM
T0	26.68	1.83	89.95	3.71	96.49	4.90	1.07	0.025
T1	27.42	4.00	91.31	10.49	67.73	6.17	0.74	0.040
T4	27.25	4.92	86.43	15.44	60.00	13.58	0.69	0.048
T8	32.32	4.17	85.42	10.00	42.83	5.73	0.50	0.046
T12	28.40	4.29	76.32	10.46	29.40	4.71	0.38	0.044

TABLE 15

Per cent transfer in types of errors for Transfer groups in learning of maze A

GROUP	T	B	E	E/B
T0				
T1	-2.77	-1.51	29.81	30.84
T4	2.14	3.91	37.82	35.51
T8	-21.14	5.04	55.61	53.27
T12	-6.45	15.15	69.53	64.49

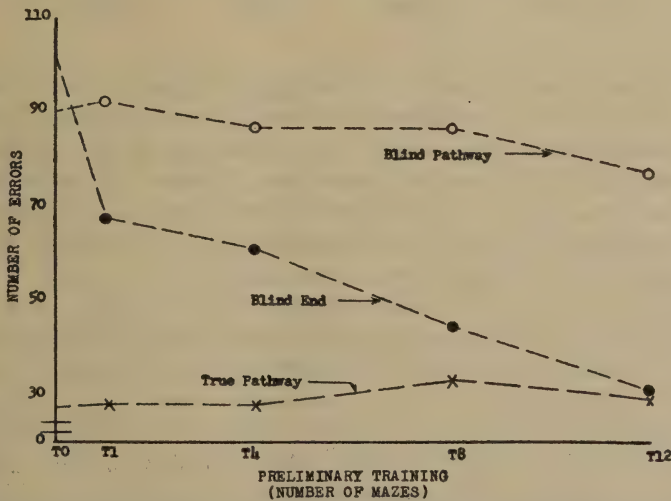


FIG. 16. TRANSFER IN NUMBER OF THREE TYPES OF ERRORS IN LEARNING OF MAZE A AFTER VARYING AMOUNTS OF PRELIMINARY TRAINING ON B MAZES

.81) and suggests that with additional units of training the transfer effect might continue to be cumulative.

The slopes of the two blind alley error curves in Fig. 16 obviously demand

that there be a consistent decrease in the number of E errors made for every E or blind alley stem, error. The full extent of the change is evident from the data of Table 16. The critical ratios of the differences between the T0 animal with no previous maze experience and each of the other groups are, in order again of increasing degree of training, 7.02, 7.04, 10.96 and 13.53. The size of these ratios indicates that the effect is of general occurrence among the individual animals of each group. That is, it apparently occurs at all levels of ability, in good records as well as poor ones. Whatever its influence on the other criteria of learning may be, training in the B mazes has clearly taught the animals to avoid complete exploration of the blind alleys that they do enter in maze A and the extent of the influence is directly proportional to the amount of experience in the shorter mazes.

In general, it may be said that the transfer of training from the B mazes to the larger pattern of maze A becomes reliably positive only after the amount of training has become cumulative to the maximum extent of the experiment—that is after all twelve such mazes have been presented. With the exception of the changing ratios of blind end errors to blind stem errors, the earlier raw scores

TABLE 16

Mean number of blind alley end (E) errors made per blind pathway (B) error for Transfer groups in learning of maze A

	T0	T1	T4	T8	T12
E/B	1.07	0.74	0.69	0.50	0.38
σ M	0.025	0.040	0.048	0.046	0.044

differences, whether in the positive or the negative direction, are relatively unreliable. It may now be considered how these facts are correlated with those of the preceding section on retroaction; the various sets of curves, thus far presented separately, will be brought together for purposes of direct comparison.

c. Relationship between cumulative transfer and relearning efficiency: maze A
In Figs. 17 through 19, transfer and retroaction curves are plotted with respect to a common base line—the level of the control group in each case. The abscissa thus represents for the transfer groups the point of zero transfer, and for the retroaction groups, the point of zero retroaction. Deviations in either direction, down for negative transfer and retroactive inhibition, up for positive transfer and facilitation in relearning, may then be plotted in terms of percentages.

The curves of Fig. 17 are the same as those in Figs. 13 and 15, and are for the three major criteria of trials to mastery, time and error scores. The vertical scale has of necessity been reduced and the retroaction curves have been inverted. Inspection of this figure reveals at first glance no very striking relationship between the two sets of curves. Further examination, however, does indicate that one or two tentative conclusions are in order.

In the first place, there is a general tendency for T12 and R12, the groups with the maximum amounts of preliminary and interpolated training, to be most bene-

tted from their training, in relation to the groups which had only four or eight mazes. In terms of time, T12 provides the most reliable increment from the control transfer condition (C.R. of 1.94, as against 1.05 for T4, 1.06 for T8), and R12 provides the least reliable decrement from the control retention condition (C.R. of 0.76, as against others of 1.31 for R4, 1.94 for R8). In terms of trials, the retroaction score for R12 is again least significant for these three groups (C.R. of 1.02, as against 2.11 for R4, 1.96 for R8), but the advantage of T12, while largest over the control T0, is not reliable (C.R. of 1.18). In terms of

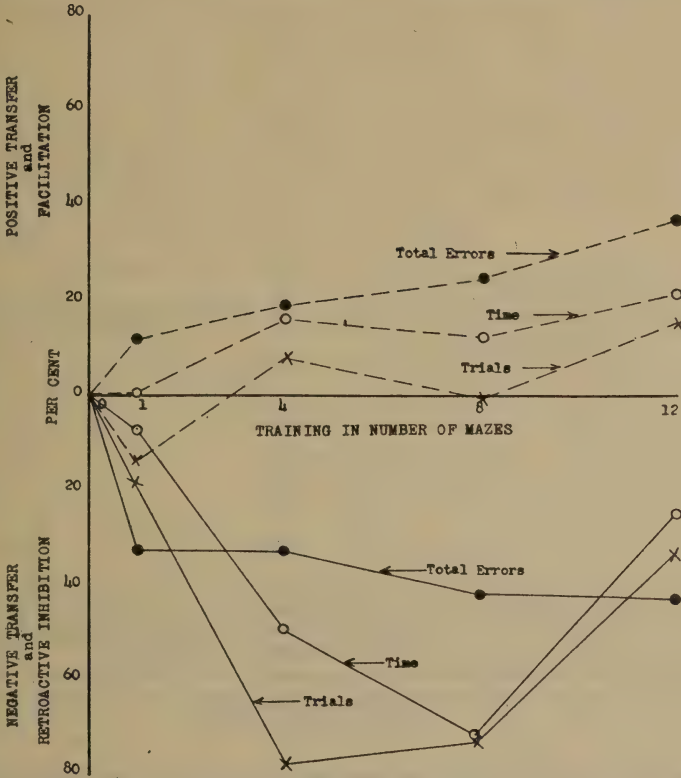


FIG. 17. RELATIONSHIP BETWEEN TRANSFER (---) AND RETROACTIVE INHIBITION (—) FOR MAZE A AFTER VARYING AMOUNTS OF TRAINING ON B MAZES

total errors, the relationship is not confirmed since T12 shows here a sharp and fairly reliable increase from T4 (C.R. of 2.03) while there is no decrease in degree of retroaction from R4 to R12. On the basis of these data alone the evidence is suggestive at best of a close association between high degree of transfer and low degree of retroaction at the upper end of the interpolation scale.

Also worthy of attention is the deviation of the curve for total errors from the other two curves. Apparently the measure which is least subject to retroactive inhibition, so far as the otherwise most susceptible middle ranges of interpolation are concerned, is also the one most benefitted, relatively, by B maze training.

The only criterion to show a reliable difference between groups R0 and R8 in transfer scores is this one of total errors (C.R. of 2.56, others of .00 for trials 1.06 for time) and it is likewise the only criterion which *fails* to give a fairly reliable difference in retroaction scores (C.R. of 1.60, others of 1.96 for trials, 1.9 for time). The suggestion, of course, is that at this point of interpolation strong positive transfer factors, relative to those measured by the other two criteria may be responsible for the greater resistance to retroactive influence.

That this conclusion is not without foundation is indicated by comparison of Figs. 18 and 19, in which transfer and retroaction percentages are plotted, for

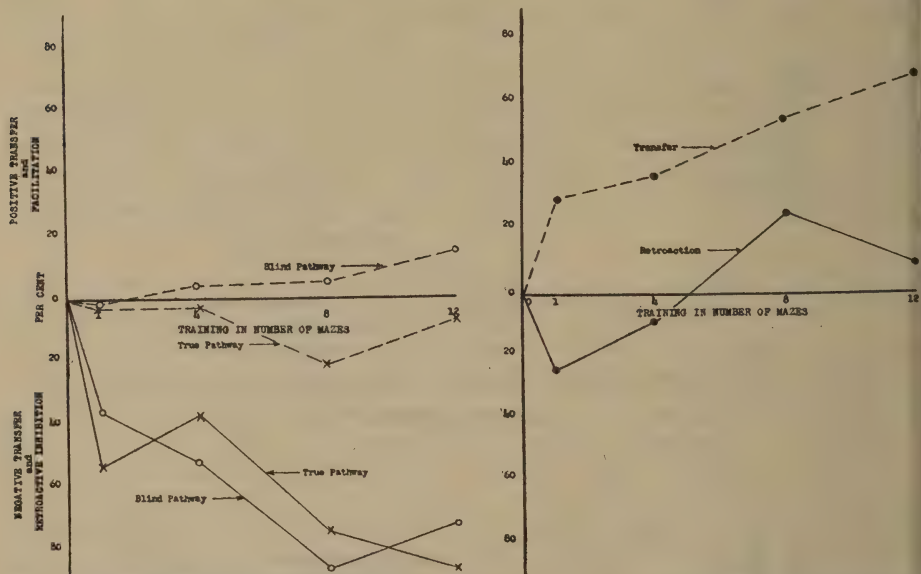


FIG. 18 (Left). RELATIONSHIP BETWEEN TRANSFER (---) AND RETROACTIVE INHIBITION (—) IN BLIND PATHWAY AND TRUE PATHWAY ERRORS FOR MAZE A AFTER VARYING AMOUNTS OF TRAINING ON B MAZES

FIG. 19 (Right). RELATIONSHIP BETWEEN TRANSFER (---) AND RETROACTIVE INHIBITION (—) IN BLIND END ERRORS FOR MAZE A AFTER VARYING AMOUNTS OF TRAINING ON B MAZES

types of errors, upon the same zero influence base line as was introduced in Fig. 17. In Fig. 18 there is, in the curves for blind pathway errors, a slight tendency for an increase in positive transfer from T8 to T12 and a similar slight decrease in retroaction from R8 to R12. These differences, however, are small and unreliable and the most that can be said is that the retroactive effect appears to have leveled off. The negative transfer curve for true pathway errors is likewise associated with increasing retroaction although the decrement from R8 to R12 is insignificant. In view of the fact that none of the differences in the two transfer curves is reliable (largest C.R. = 1.24) it may be assumed that the net transfer effects in these measures are practically zero over the complete range of interpolation used, and that such indifferent transfer results are associated with

significant degrees of retroaction, which appear to reach their peak about R8 (C.R.'s of 2.39 and 2.55 in T and B errors respectively).

Inspection of Fig. 19 reveals a strikingly different picture. The retroaction curve for E errors shows inhibition only for one and four interpolated tasks and actual facilitation for eight and twelve. Although the difference between R8 and R0 is not very reliable (C.R. of 1.08) that between R8 and R1 is twice its sigma and indicates that the increased amount of interpolation has produced a relatively significant reduction in number of blind end errors. The corresponding transfer curve is, as has been noted, highly reliable at all points. The difference between R1 and R8, for example, is about five times its sigma, indicating that the same increased amount of training from one to eight mazes has produced a reliable reduction in E errors in original learning of maze A. Aside from any specific points, the general trend and level of these two curves offer an interesting contrast with those in Fig. 18. It is apparent that the *only* transfer measure which shows a positive transfer influence that is at all reliable is accompanied by a considerable reduction in retroaction for R4, R8 and R12, and probably an actual facilitating effect for the latter two groups.

This close correspondence between the transfer and retroaction groups with respect to blind alley errors is further confirmed by Fig. 20, based upon the data given in Tables 11 and 16. When the number of blind end entrances that are made for every blind stem error is computed the curves of this figure emerge. The high statistical reliability of these curves is evident from the critical ratios of the differences between the control conditions and the last two work conditions: 4.15 and 3.22 for retroaction, 10.96 and 13.53 for transfer. It is clear that B maze training, whether inserted as interpolated learning in the retroaction situation, or as preliminary learning in the transfer situation, is highly beneficial in reducing the tendency to explore the whole blind alley once the stem has been entered.¹⁷

The results of the comparisons thus far made may be summarized as follows: in terms of the three major criteria of trials, time and total errors the greatest transfer and least retroactive effects are found for the middle amounts of interpolation in the same measure (total errors); and there is some suggestion that increased transfer effects at the extreme upper end of the scale (T12) are accompanied by decreases in retroactive effect (R12). Although this tendency is not confirmed by the total errors measure, analysis of errors into the three types reveals that the retroactive effect is reliable only for those types (T and B) which show no reliable transfer effect, and that it is wholly lacking (and probably gives way to actual facilitation) when there is a strong and progressive positive transfer influence (E). Comparison of the change in the ratio of blind end to blind stem errors further confirms the facilitative effect, indicating that regardless of the absolute number of blind alleys entered there is a progressive decrease in the tendency to explore the whole alley, and that this change is approxi-

¹⁷ The advantage of the retroaction curve is probably of no importance, although the influence of the original learning of maze A may be seen in the fairly reliable difference between the two control groups, TO and RO (C. R. = 2.31).

mately the same for the same amount of B maze training whether it is inserted as interpolated learning or as preliminary training.

The results would seem to be satisfied, in the main, by the assumption that the retroactive influence is generally at a maximum in the middle amounts of interpolated training and is reduced or leveled off at the higher end of the scale only when the positive transfer effects have become cumulatively stronger. Further

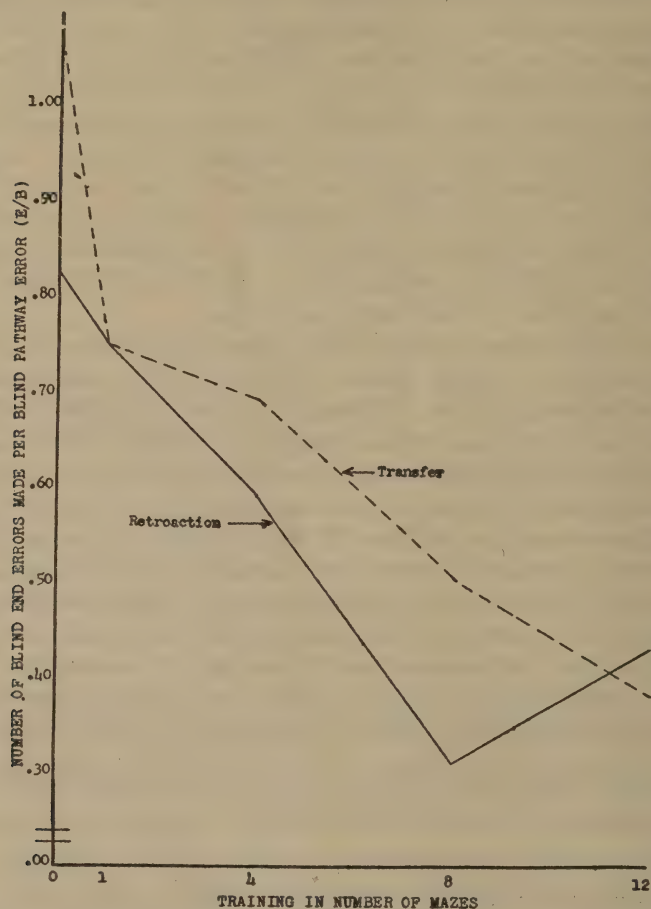


FIG. 20. RELATIONSHIP BETWEEN TRANSFER (---) AND RETROACTIVE INHIBITION (—) IN THE NUMBER OF BLIND END ERRORS MADE PER BLIND PATHWAY ERROR FOR MAZE A AFTER VARYING AMOUNTS OF TRAINING ON B MAZES

discussion of these results will be delayed until after the corresponding curves based on retention of the first B maze have been presented.

3. Cumulative transfer and retroactive inhibition in the relearning of an easy maze problem, incompletely learned

a. *Retroactive inhibition: maze B.* As outlined under *Plan of Experiment*, a retention test on the first B maze learned by all groups was administered on the

day immediately following the final mastery of the larger maze pattern (maze A). The four transfer groups (T1, T4, T8 and T12), whose maze training was begun with the first B maze, have been classified for this part of the experiment as BR (B maze Retroaction) groups, with the number of mazes interpolated between first learning and relearning of maze B1 indicated by the figure following the symbol for Retroaction. The manner in which these supplementary retroaction conditions have been derived from the maze A transfer conditions is shown in Table 3 (p. 10).

It is obvious that every interpolated learning condition must necessarily be concluded with the learning to mastery of maze A, following the earlier training on the B mazes. Thus the interpolated work conditions were: for group BR1, maze A only; for group BR4, 3 additional B mazes and maze A; for group BR8, 7 additional B mazes and maze A; and for group BR12, 11 additional B mazes and maze A. Each group was then tested on its first B maze.

In order that percentage of retroactive inhibition might be computed for the retention records of the BR groups a control or rest condition was included in the

TABLE 17

Means and standard errors in time (sec.) for B Retroaction groups in learning of maze B1

GROUP	TOTAL 10 TRIALS		FIRST TRIAL		FIRST 5 TRIALS		SECOND 5 TRIALS	
	M	σM	M	σM	M	σM	M	σM
BR0	1116.59	171.09	241.64	36.80	737.14	103.34	379.45	72.46
BR1	998.35	98.40	268.04	28.96	748.00	74.92	250.35	31.17
BR4	1192.18	116.54	266.25	29.62	865.93	89.11	326.25	49.18
BR8	1071.42	105.57	275.54	29.42	762.25	77.02	309.17	41.34
BR12	1126.96	140.33	285.72	31.44	808.64	85.72	318.32	10.11

experiment (BR0). These animals took their B1 training on the third day of the cycle, just as did all other groups except R0, and then "rested" until the retention test thirteen days later. The differences between their retention scores and those of the various work groups will therefore reflect the influence of the interpolated learning.

The degree of learning that was attained by these various groups on their original ten trials on B1 is indicated by the fact that approximately half of the animals (51.59 per cent) achieved at least one errorless trial and that approximately one quarter (26.19 per cent) achieved at least three such trials. The original learning and retention test records have been arranged in Tables 17 through 20.¹⁸

The two curves of Fig. 21 are drawn from the percentages which the differences between each group and the control retention group (BR0) form of

¹⁸ The critical ratios for the largest differences between original learning means were for the most part insignificant. All the differences between two groups whose relearning scores are involved in important comparisons were uniformly small and insignificant. Slight deviations in original learning records will therefore be disregarded in the treatment of relearning data.

TABLE 18

Means and standard errors in errors for B Retroaction groups in learning of maze B1

GROUP	TOTAL 10 TRIALS		FIRST TRIAL		FIRST 5 TRIALS		SECOND 5 TRIALS	
	M	σ M	M	σ M	M	σ M	M	σ M
BR0	124.14	12.96	27.64	3.73	89.64	7.39	36.32	5.92
BR1	124.42	13.09	37.54	4.01	96.15	11.87	23.58	3.77
BR4	144.11	12.60	33.18	3.83	87.07	14.87	33.54	4.50
BR8	132.54	13.46	38.04	3.67	101.17	9.49	31.63	6.25
BR12	122.72	16.20	34.76	2.96	96.84	8.60	25.88	9.19

TABLE 19

Means and standard errors in time (sec.) for B Retroaction groups in relearning of maze B1

GROUP	TOTAL 10 TRIALS		FIRST TRIAL		FIRST 5 TRIALS		SECOND 5 TRIALS	
	M	σ M	M	σ M	M	σ M	M	σ M
BR0	447.73	67.71	77.18	12.08	325.18	43.39	167.18	27.89
BR1	528.65	61.81	110.69	17.45	344.27	44.84	184.38	21.89
BR4	405.86	44.27	88.25	13.46	261.18	31.39	144.54	18.18
BR8	415.67	39.52	76.38	12.43	251.50	24.16	176.04	24.93
BR12	381.92	34.88	65.08	7.36	232.36	19.82	149.56	17.57

TABLE 20

Means and standard errors in errors for B Retroaction groups in relearning of maze B1

GROUP	TOTAL 10 TRIALS		FIRST TRIAL		FIRST 5 TRIALS		SECOND 5 TRIALS	
	M	σ M	M	σ M	M	σ M	M	σ M
BR0	41.32	7.72	10.35	2.19	32.45	4.15	9.27	3.03
BR1	42.00	5.44	14.54	2.55	33.31	4.39	9.31	1.67
BR4	35.32	5.97	13.39	2.05	27.36	4.42	7.96	1.94
BR8	38.54	4.36	10.33	1.40	26.54	3.79	12.00	1.80
BR12	31.20	5.13	8.72	1.47	22.00	3.13	9.24	2.47

TABLE 21

Per cent savings and per cent retroactive inhibition in time for B Retroaction groups in relearning of maze B1

GROUP	PER CENT SAVINGS				PER CENT R.I.			
	Total 10 tr.	First tr.	First 5 tr.	Second 5 tr.	Total 10 tr.	First tr.	First 5 tr.	Second 5 tr.
BR0	57.21	68.06	55.89	55.94				
BR1	47.05	58.70	53.97	30.35	10.66	43.42	5.87	10.29
BR4	65.96	66.85	69.84	55.70	-15.04	14.34	-19.68	-13.54
BR8	61.20	72.28	67.01	43.06	-12.99	-1.04	-22.35	5.30
BR12	66.11	77.22	71.27	53.06	-20.06	-15.68	-28.54	-10.54

TABLE 22

Per cent savings and per cent retroactive inhibition in errors for B Retroaction groups in relearning of maze B1

GROUP	PER CENT SAVINGS				PER CENT R.I.			
	Total 10 tr.	First tr.	First 5 tr.	Second 5 tr.	Total 10 tr.	First tr.	First 5 tr.	Second 5 tr.
BR0	66.72	62.55	63.79	74.47				
BR1	66.24	61.72	65.36	60.52	0.01	40.48	2.65	0.43
BR4	75.49	59.64	68.58	76.27	-14.52	29.47	-15.69	-14.13
BR8	70.92	72.84	73.77	62.06	6.75	-0.02	-18.21	29.45
BR12	74.58	74.91	77.28	64.30	-24.49	-15.75	-32.20	0.70

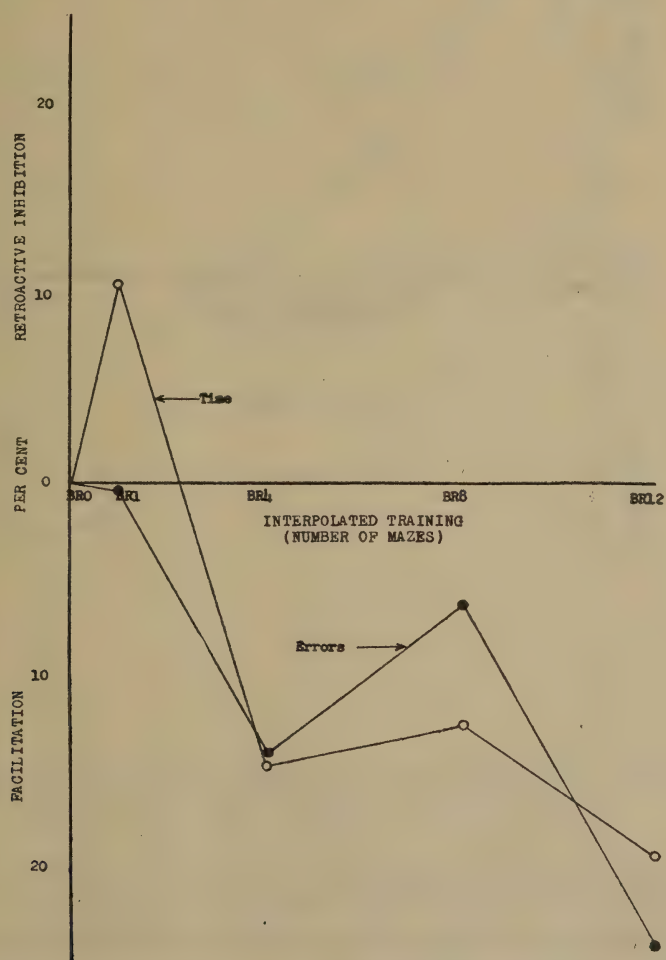


FIG. 21. RETROACTIVE INHIBITION, OR FACILITATION, IN TIME AND ERRORS IN RELEARNING OF MAZE B AFTER VARYING AMOUNTS OF INTERPOLATED MAZE TRAINING

the latter's total scores. They are thus "retroaction" curves in the sense that they represent the influence of the interpolated learning upon retention of the original learning. A brief inspection of the figure, however, reveals that there is very little retroactive inhibition involved and that the effect of the interpolated learning was by and large facilitating. Moreover, with the exception of the

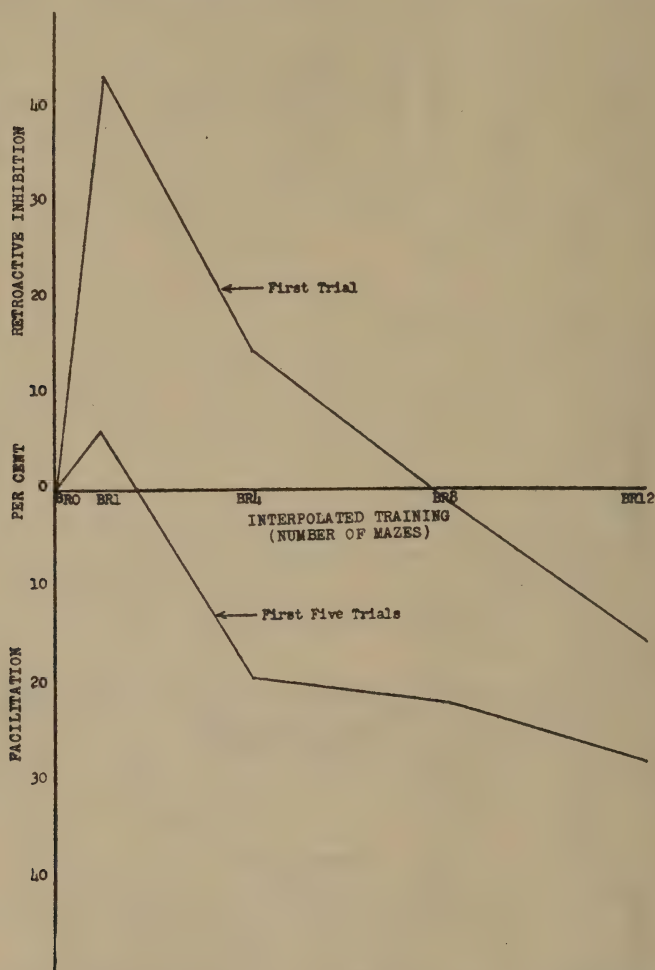


FIG. 22. RETROACTIVE INHIBITION, OR FACILITATION, IN TIME IN RELEARNING OF MAZE B AFTER VARYING AMOUNTS OF INTERPOLATED MAZE TRAINING

inversion from group BR4 to group BR8, the amount of facilitation seems to be a direct function of the amount of interpolated training that was accorded each group. The initial rise in the time curve, indicating a slight degree of inhibitory effect, is far from reliable (C.R. of 0.56). Also unreliable, however, are both differences between the BR0 and BR12 groups, with critical ratios of 1.09 for errors and 1.13 for time. The difference in time scores between BR12 and BR1

is more than twice its sigma (C.R. of 2.07), the chances being about 98 out of 100 that it is a real one. This fact, together with the general trend of the curves, does suggest that the facilitative effect is genuine. At any rate it is clear that there has been no significant inhibitory influence, even for the animals with the poorest retention records.

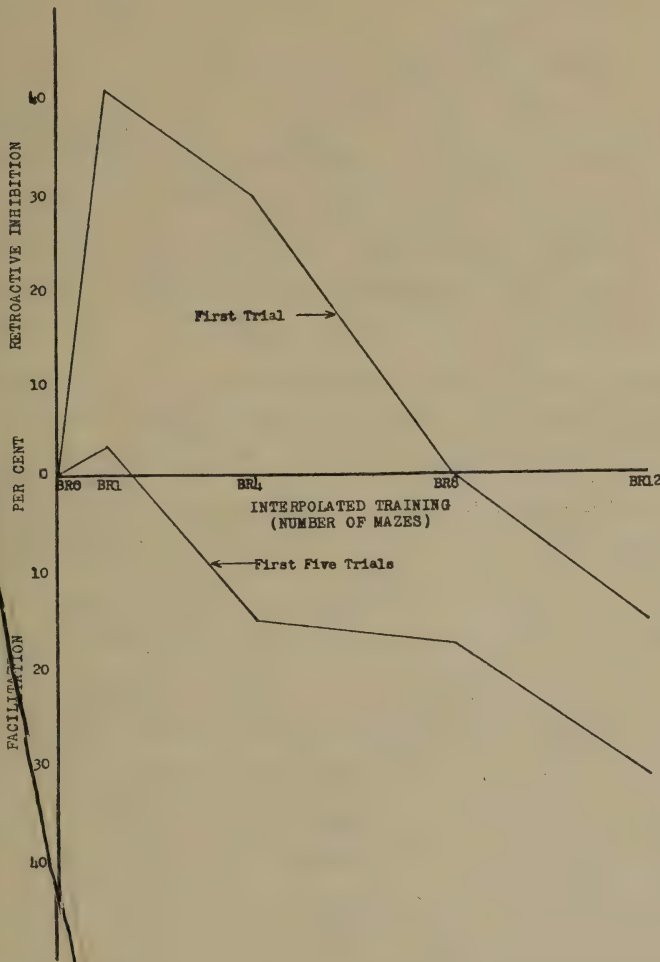


FIG. 23. RETROACTIVE INHIBITION, OR FACILITATION, IN ERRORS IN RELEARNING OF MAZE B AFTER VARYING AMOUNTS OF INTERPOLATED MAZE TRAINING

When the first trial and the first five trials are considered together, the curves of Figs. 22 and 23 appear. From them it is apparent that the inhibition which did occur was largely confined to the first retention trial. Even here, however, the net result is facilitating by each measure for the group with the greatest amount of previous maze experience. The peak of the inhibitory effect on the first trial is a BR1 for each measure but the variations from the control group scores are not reliable (C.R.'s of 0.59 for time, 1.25 for errors). On the other

hand, the differences between BR12 and the control condition are likewise statistically insignificant, being for both time and errors less than their respective sigmas. That the trend is reliable, nevertheless, is suggested by relatively high critical ratios for the differences between the groups with the greatest inhibitory and the greatest facilitative effects, BR1 and BR12. These ratios are, for time and errors respectively, 2.41 and 1.98, indicating that the chances of confirming the differences if the conditions were duplicated are 99 and 98 out of 100.

More direct evidence that the interpolated training has produced a genuine facilitative effect, at least in the first five trials of the retention test, is provided by the lower curves of Figs. 22 and 23. Here the critical ratios between the control group and group BR12 are fairly large, being 1.95 for time and 2.01 for errors. The chances are roughly 98 out of 100 that the facilitative effect would be confirmed under similar experimental circumstances. The clear superiority of the BR12 animals within the first half of the learning session is also indicated by the fact that 76 per cent of the group had achieved at least one errorless run at the end of five trials, with corresponding percentages for the other groups ranging from 50 to 61.

Percentages of inhibition and facilitation fail to show any consistent pattern in the second five trials. The differences either way are small and far from reliable. The lack of a uniform trend in the last half of the learning period need not vitiate conclusions drawn from the regularities of the first half. It may be noted that the numbers involved, especially with respect to errors, are considerably smaller in the second half, and that the differences between totals, therefore, may be expected to be somewhat less reliable. Further speculation on the reason for the variation will not be pursued since the data offer no enlightenment.

Additional evidence that increasing amounts of interpolated training tend to improve rather than retard relearning performance is presented in Fig. 24, from the B1 relearning records of those original R groups which had learned maze A to mastery before their first ten trials on the first B maze. Although the extent of the proactive inhibition of relearning that has entered into the records of these animals is not known, it is difficult to see how this factor could operate to increase the regularity of the trends already apparent from the BR curves. These records, while they must be regarded with due caution, may be considered as capable of corroborating the results given above, even if they could not by themselves carry sufficient weight to establish general conclusions.

Because it was not convenient to provide a special control condition for these groups, it is impossible to compute percentages of retroactive inhibition or of facilitation. The curves of Fig. 24 are therefore drawn from the raw data in time and error scores.¹⁹ It is clear that they are in essential agreement with

¹⁹ Original learning records of these four groups were, with three exceptions, devoid of statistically reliable differences. The exceptions were for differences between groups 8 and 12 in total time scores, 12 and 1 in errors, second five trials, and 8 and 12 in time, second five trials. Since none of these exceptions involves any pair of salient points in the curves, the gradients may be regarded as independent of the possible influence of such deviations in original learning.

ose of Figs. 21, 22 and 23. With the exception of the expected reversal as the peak of retroaction is apparently reached, after one or four interpolated tasks, there is in all eight curves not a single inversion. The uniformity is found, should also be noted, in the second five relearning trials, where it is least evident for the BR conditions. The critical ratios for all these differences, in conformity with the greater regularity of the trends, are consistently larger than

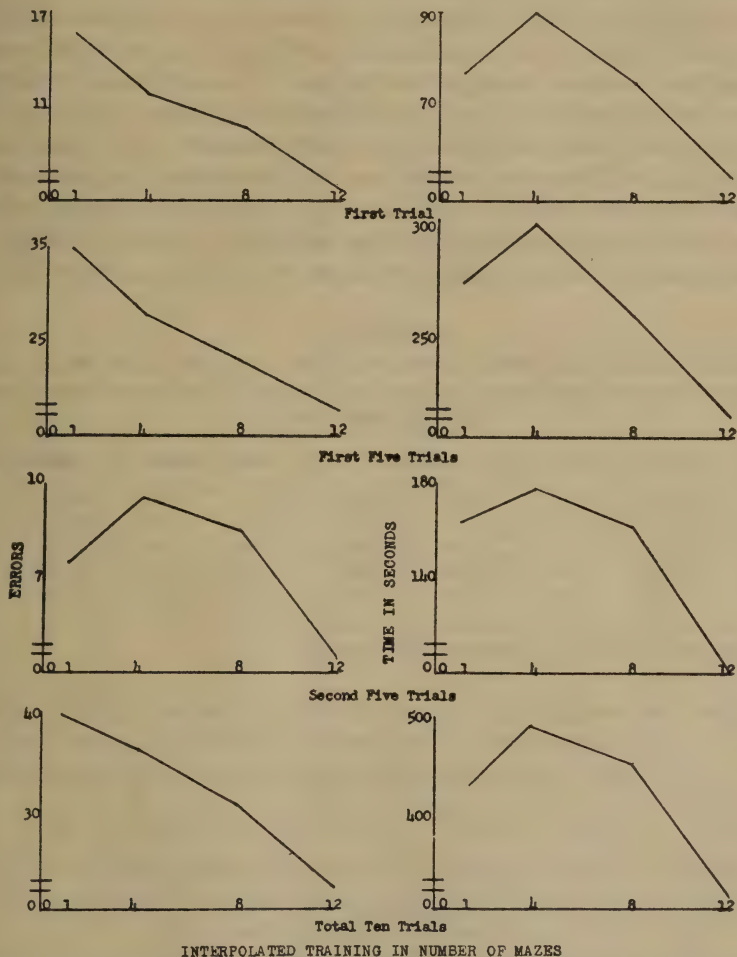


FIG. 24. RETROACTIVE INHIBITION: MAZE B. FOR EXPLANATION SEE TEXT

those of the BR group differences. The critical ratios between the group with twelve interpolated tasks, which Fig. 24 shows to be far superior in every measurement, and those groups with the lesser amounts of interpolation, are provided in Table 23.

That the advantage which accrues from the maximum amount of interpolated training is generally of high reliability is indicated by the fact that of the six-

teen comparisons between the group with twelve interpolated mazes and two groups having least training, eleven of the differences are more than two standard errors, and four of these are more than three times their standard errors. Even in the comparisons between the group with four less interpolated mazes, three of the eight critical ratios are well over twice their standard errors. These results may be accepted as valuable supplements to the statistically reliable, if methodologically sounder, curves of Figs. 21 through 23.

On the basis of the definite tendencies exhibited in the results discussed in this section it may be stated with considerable confidence that under the conditions of learning and retention employed in this part of the experiment, efficiency of relearning varies directly with amount of interpolated maze experience. There is some suggestion of an early inhibitory effect, especially in the first relearning trial, although the differences involved are without statistical significance. The critical ratios of differences between the groups with little interpolated learning and those with the maximum amount, are sufficiently large to indicate clearly that when such increments of maze experience are added a genuinely facilitating

TABLE 23

Critical ratios for differences between the means of the group with twelve mazes interpolated between learning and relearning of maze B1, and those of the groups with one, four and eight interpolated mazes

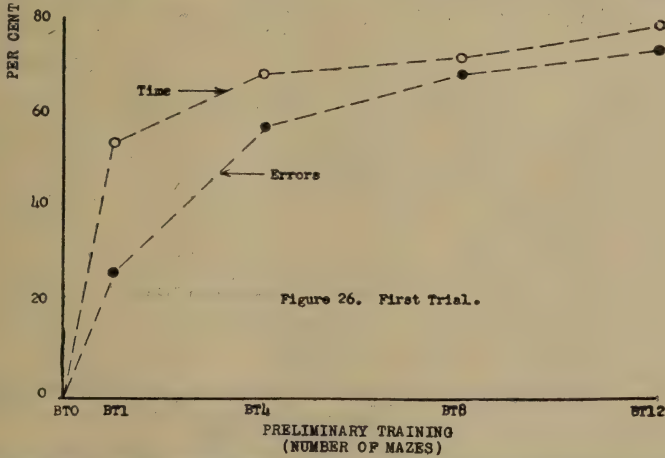
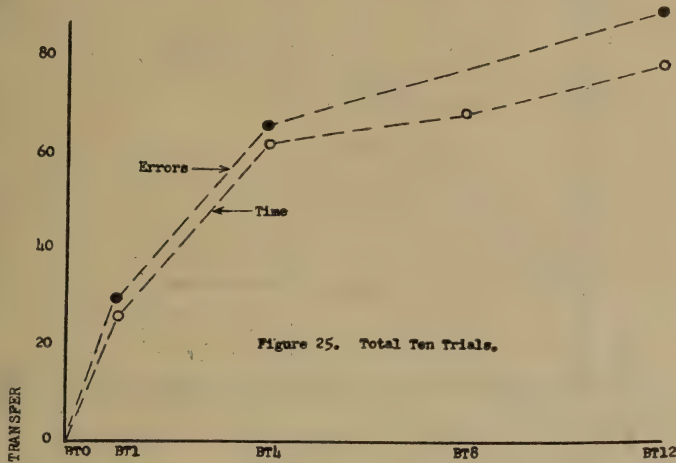
GROUPS COMPARED*	TOTAL 10 TRIALS		FIRST TRIAL		FIRST 5 TRIALS		SECOND 5 TRIALS	
	Time	Errors	Time	Errors	Time	Errors	Time	Errors
1-12	2.06	2.48	1.50	3.48	1.80	2.58	3.84	1.41
4-12	2.93	3.03	1.80	2.49	2.40	2.25	3.02	1.74
8-12	2.21	1.70	1.47	2.52	1.50	1.38	2.39	1.45

* Figures refer to number of interpolated mazes.

effect appears, especially within the first half of the retention test. This conclusion is strongly corroborated and extended to the second half of the learning period by the highly reliable curves of Fig. 24, although full weight cannot be accorded these data because of the complication mentioned.

b. *Cumulative transfer: maze B.* In order that the retroactive effects upon maze retention of varying amounts of interpolated maze training might be compared with the transfer effects of corresponding amounts of training, the transfer curves of Figs. 25 through 28 have been constructed. Since it was impossible under the circumstances of the main experiment, to provide transfer conditions strictly analogous to the interpolated conditions, it was necessary to utilize data that were already available. In doing this the main objective was to have corresponding points on the two sets of curves equated in amount of training, interpolated and preliminary. The control condition (BT0) is of course provided by the original learning records of all five groups that had a B maze as their first learning problem (T1, T4, T8, T12 and BR0). Because the R animals had learned maze A as their first problem, and then learned varying numbers of

mazes, their records on certain of the B mazes could be used for B maze trans-conditions (BT groups). For example, all of the experimental R animals could be put into group BT1 since they had as preliminary training only maze A and were thus in this respect equated with the corresponding retroactive condition, BR1, which had the same maze as its only interpolated task. Similarly, groups BT4 and BR4 had, as preliminary and interpolated training, maze A and

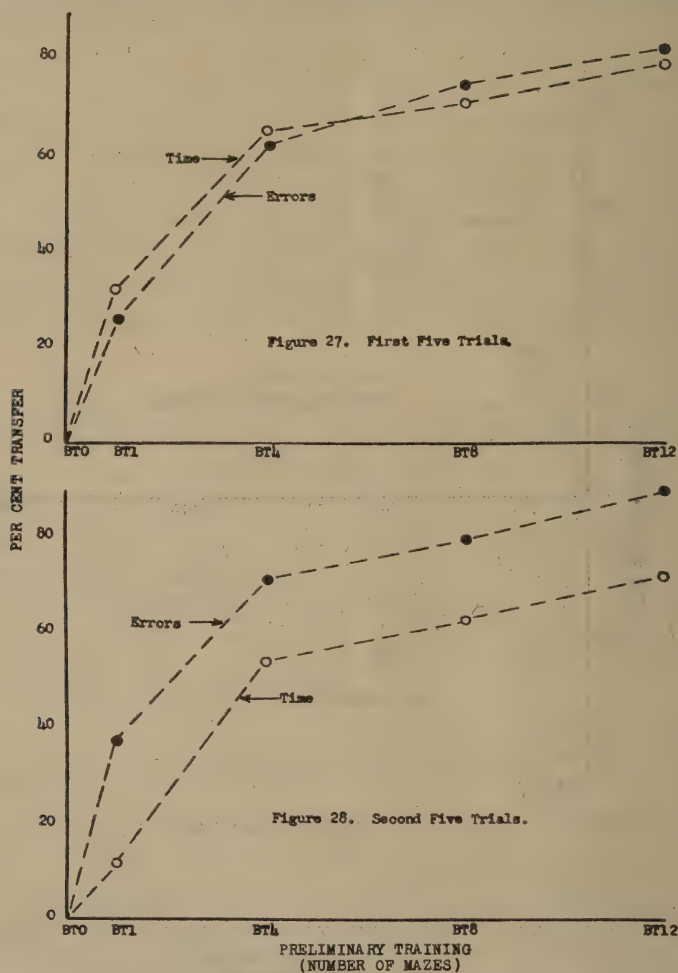


FIGS. 25 AND 26. PER CENT TRANSFER IN TOTAL TEN TRIALS (FIG. 25) AND ON FIRST TRIAL (FIG. 26) OF LEARNING MAZE B AFTER VARYING AMOUNTS OF PRELIMINARY MAZE TRAINING

three other B mazes. In this case it was the fourth interpolated B maze learned by the R rats whose data were utilized in the transfer condition. Records from mazes B8 and B12 were used in the remaining two transfer conditions. Reference to Table 4 (p. 10) will help to clarify the situation.²⁰

²⁰ It is obvious that there are important differences in the learning conditions under which the corresponding data for the two sets of curves were obtained. In general, the

The curves themselves require little comment. They obviously bear a strong resemblance to the curves of Figs. 5 through 8, which show the cumulative transfer effects of an equal number of mazes when another short B maze, rather than maze A, is learned first. While a somewhat greater initial transfer effect seems to result from the ten trials on maze B1 than from the complete learning of maze



FIGS. 27 AND 28. PER CENT TRANSFER IN FIRST FIVE TRIALS (FIG. 27) AND SECOND FIVE TRIALS (FIG. 28) OF LEARNING MAZE B AFTER VARYING AMOUNTS OF PRELIMINARY MAZE TRAINING

A, it does not seem to matter much which maze came first after three additional short mazes have been learned (*cf.* also footnote 12, p. 22). On the whole, the

learning test for the transfer groups came somewhat sooner after training than did the relearning test for the retroaction groups. In the training sequence, also, maze A invariably came first in the preliminary training of the transfer groups and last in the interpolated training of the retroaction groups. The significance of these differences, and the way in which they may have influenced the obtained results, will be discussed in the next section.

curves agree in showing a negatively accelerated slope with a decided leveling off as the amount of training approaches the maximum given.

The differences between the control condition BT0 and the remaining groups are so large in relation to their standard errors that there is little question of the reliability of the gradient. Critical ratios of the differences between BT0 and the remaining groups in order are, for total time scores, 4.22, 11.63, 12.86 and 15.06, and for total error scores, 4.98, 13.38, 15.06 and 16.51. Other ratios between successive points on the curves are also large (between BT8 and BT12, for example, 3.15 and 2.34 in total time and errors). Critical ratios for the sub-total scores are correspondingly significant and there is no need for reproducing them here.

c. Relationship between cumulative transfer and relearning efficiency: maze B. Total time and error scores for the transfer and relearning conditions have been plotted from the same abscissa in the curves of Fig. 29. The base line represents the level of zero influence from training—no transfer in learning and neither inhibition nor facilitation in relearning. Positive transfer and facilitation in relearning are represented as deviations above the base line, negative transfer and inhibition in relearning, as deviations below the base line.

It is apparent from the figure that there is no linear relationship between the net amount of positive transfer effect that is produced in learning and the amount of facilitation that is found in relearning after an equal number of mazes. Thus while a single maze (A) facilitates the learning of a shorter maze (B1), it has very little definite effect upon relearning of the same maze when it is inserted as an interpolated problem.²¹ On the other hand, it is evident that as the training in either case becomes increasingly cumulative there is a definite trend toward facilitation in both learning and relearning. The facilitating effect in relearning is most marked after twelve interpolated mazes have been learned, and the same thing holds true for the transfer conditions. However, the largest absolute increment from one condition to the next occurs, for both transfer and relearning, after the learning of four maze problems. At this point in the curves, 79 per cent of the maximum transfer effect and 66 per cent of the maximum facilitation in relearning have already been gained. Additional increments of training then have relatively less effect. This is shown by the actual inversion in the relearning curve at BR8 and by the fact whereas the transfer learning records of group BT4 showed a 129 per cent improvement over those of group BT1, the improvement was only 14 per cent from BT4 to BT8 and 11 per cent from BT8 to BT12.

When only the first five trials are considered, the curves of Fig. 30, plotted from the same zero influence base line, appear to show the relationship even more regularly. With the exception of the first interpolated condition in the relearning curve, there is an unmistakable parallel between the general trend of each curve. One important difference, however, may be observed. The negative acceleration of the transfer curve, as contrasted with the roughly linear slope of the re-

²¹ Since the transfer effect of one B maze upon learning of maze A (condition T1) was small and insignificant, these results cannot be attributed to any important differences in the amount of learning activity involved in mastering maze A, in the transfer and relearning situations.

learning curve, may be interpreted as meaning that negative transfer (interference) effects are *relatively* stronger with smaller amounts of interpolated training than they are with smaller amounts of preliminary training. This conclusion may also be drawn from the data plotted in Fig. 29, but it is better

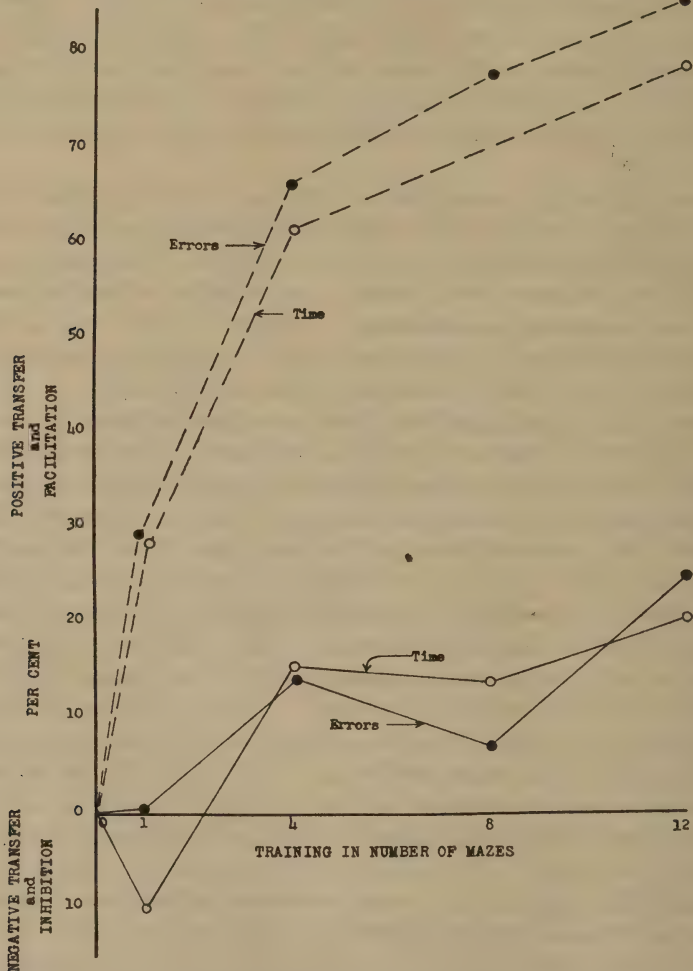


FIG. 29. RELATIONSHIP BETWEEN TRANSFER (---) AND INHIBITION OR FACILITATION IN RELEARNING (—) FOR TOTAL SCORES ON MAZE B AFTER VARYING AMOUNTS OF MAZE TRAINING

indicated in the more regular, and statistically more reliable, curves based on the first half of the relearning test.²²

²² The differences between the control condition and group BR12 are fairly reliable for this curve (C. R.'s of 1.95 and 2.01 for time and errors), the chances being about 98 out of 100 that they represent genuine differences in group learning performances. All transfer curves are highly reliable, as was pointed out in the preceding section, with critical ratios ranging from 2 and 3 to 15 and 16 as more widely separated points on the curve are compared.

It is probable that the facilitating effect found in relearning after eight and twelve interpolated mazes would have been somewhat greater were it not for certain of the conditions under which the training was provided. Since mastery of maze A immediately preceded the retention test on the first B maze, it is pertinent to ask whether this factor might not have had a differential effect upon efficiency of relearning after various amounts of training. Evidence in the

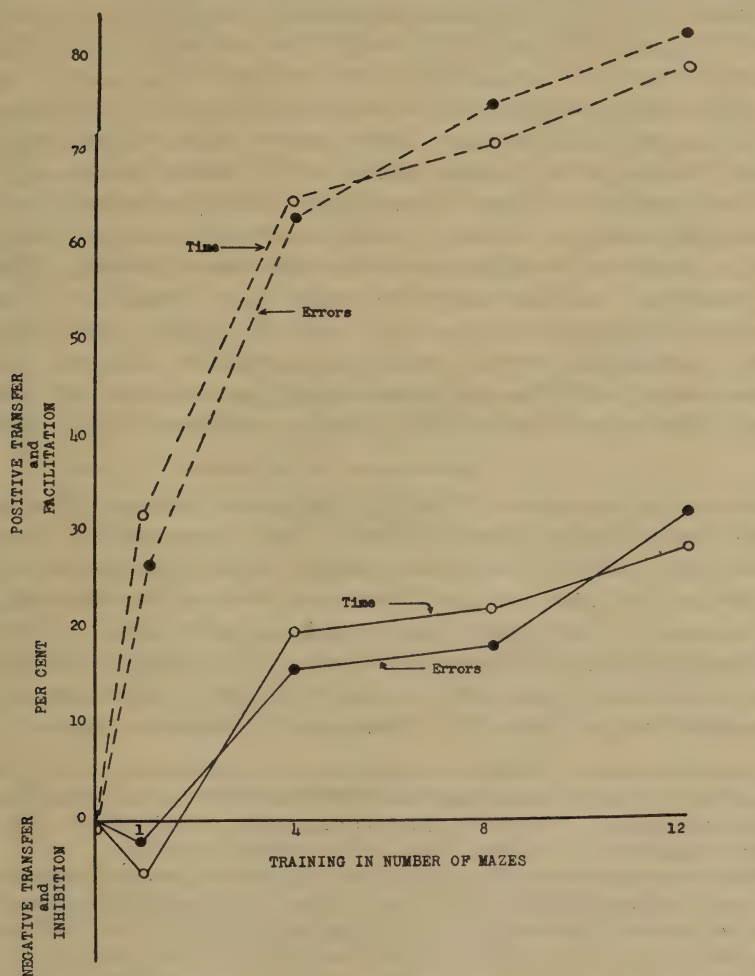


FIG. 30. RELATIONSHIP BETWEEN TRANSFER (---) AND INHIBITION OR FACILITATION IN RELEARNING (—) FOR FIRST FIVE TRIALS ON MAZE B AFTER VARYING AMOUNTS OF MAZE TRAINING

affirmative may be adduced from comparisons between the relearning records of groups BR4, BR8, and BR12 and the records that each group made on its last interpolated B maze. The critical ratios of these differences are sufficiently high to justify the conclusion that interpolation of maze A has a negative transfer effect upon relearning of maze B1 when maze running ability is at a relatively high level following the daily learning of eight or twelve successive mazes (*cf.*

Figs. 5 through 8).²³ This conclusion rests upon the reasonable assumptions that the maze originally learned should prove no more difficult on relearning than would a completely new maze, and that significantly negative transfer effects would not be produced over the ten day interval by normal non-maze activities.²⁴ If these are true, the reliable decrement following learning of maze A may safely be ascribed to negative transfer from maze A. It may therefore be deduced that, had maze A not been interpolated immediately preceding the retention test of maze B1, groups BR8 and BR12 would have made better relearning records, especially in relation to group BR4,²⁵ and the slope of the curve at the upper end of the interpolation range would be somewhat accelerated. For the same reasons, it is also apparent that had maze A been inserted as the final problem of the preliminary training in the transfer conditions, the transfer curves would be lower and would thus show a closer correspondence to the obtained retroaction curves.

These inferences are of value in indicating that the obtained results are not merely a function of the differences in the conditions of training. They suggest that, whichever conditions might be changed so as to make them coincide with the other, the change would very likely result in a greater, rather than a lesser, degree of association between transfer and retroaction measures. Comparison of these results with those based upon transfer and relearning curves from maze A may therefore be attempted with adequate confidence in their validity.

DISCUSSION OF RESULTS

In presenting the results of this study comparisons between curves based upon transfer and relearning records of mazes A and B have generally been avoided, in order that a more thorough interpretation might be developed at one time. It is obvious that there is a great discrepancy between the relearning curves of the two mazes. Interpolated maze training seems to have had, in general, a significantly inhibitive influence on relearning of the difficult, well-learned maze A and to have had a significantly facilitative influence on relearning of the easier, incompletely learned maze B.²⁶ These general trends are apparent in Fig. 31,

²³ In total time and error scores the ratios are, for the increment observed in BR4 records, 0.78 and 2.63, and for the decrements found in BR8 and BR12 records, 2.55 and 2.47, and 3.63 and 3.05, respectively. The chances that the impairment in performance of the latter two groups was genuine are about 99.4 (BR8) and 99.9 (BR12) out of 100.

²⁴ Sound logic supports the first assumption, experimental evidence the second. Bunch and Lang (8) have shown that the transfer effect from mastery of one maze to learning of another becomes increasingly positive as the time interval between the two experiences is lengthened, up to about thirty days, and that even after four months it is still as large as when the two mazes are learned together. There are no reasons for supposing that this relationship should be reversed in the case of cumulative transfer from training on several successive mazes.

²⁵ It is also probable that interpolation of maze A immediately preceding relearning had, for group BR4, a net positive transfer effect, but this conclusion is not possible from the data at hand, since there is no way of determining the improvement that would have taken place in the absence of maze A.

²⁶ The fact that maze A was given as one of the interpolated problems in the case of maze B retention cannot be held responsible for the difference, since it has been shown that if maze A had not been interpolated the facilitating effect in relearning of maze B would probably have been even greater (see p. 49ff.)

in which inhibition and facilitation in relearning have been plotted from the same zero influence base line in terms of total scores. Equal amounts of interpolated maze training have clearly influenced retention in wholly different directions. If all work interpolated conditions are considered together, regardless of amount of training, the average *inhibition* in relearning of maze A was 44.20 and 38.05 per cent for total time and error scores respectively, and the corresponding amount of *facilitation* in relearning of maze B was 9.36 and 11.44 per cent. When only the maximum effects are considered, however, the actual dif-

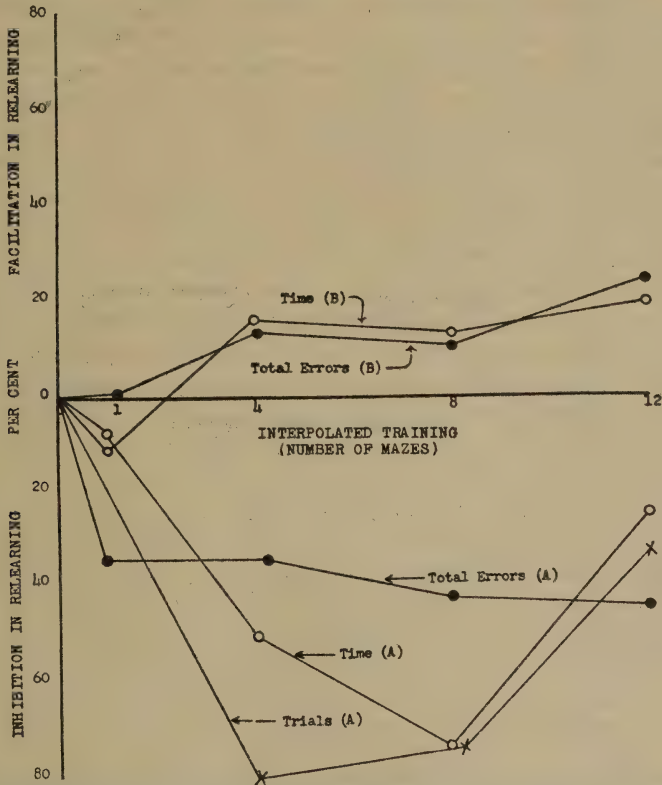


FIG. 31. INHIBITION OR FACILITATION IN RELEARNING OF A DIFFICULT MAZE PROBLEM, LEARNED TO MASTERY (MAZE A), AND AN EASY MAZE PROBLEM, INCOMPLETELY LEARNED (MAZE B), AFTER VARYING AMOUNTS OF INTERPOLATED MAZE TRAINING

ferences are more adequately represented. After eight interpolated mazes, for example, the relearning of maze A requires about 75 per cent more trials and time, and results in about 40 per cent additional errors, than were necessary when there had been no interpolated maze training. After twelve interpolated maze problems, on the other hand, the relearning trials of maze B were completed with 20 per cent less time and errors than were made in an equal number of trials by animals with no interpolated training. Intermediate effects confirm these results in general, although interpolation of a single maze problem is seen to have considerably less influence, in relearning of either maze.

Interpretation of relearning efficiency is facilitated by the cumulative transfer and relearning curves of Fig. 32. In order to have relearning and transfer effects represented by single curves, the relearning data of Fig. 31 have been averaged and plotted from the same zero influence base line together with the appropriate cumulative transfer curves, similarly averaged. Without regard to the specific slope of the curves, it is apparent from the relative percentage levels that a high degree of retroactive inhibition in relearning is associated with a

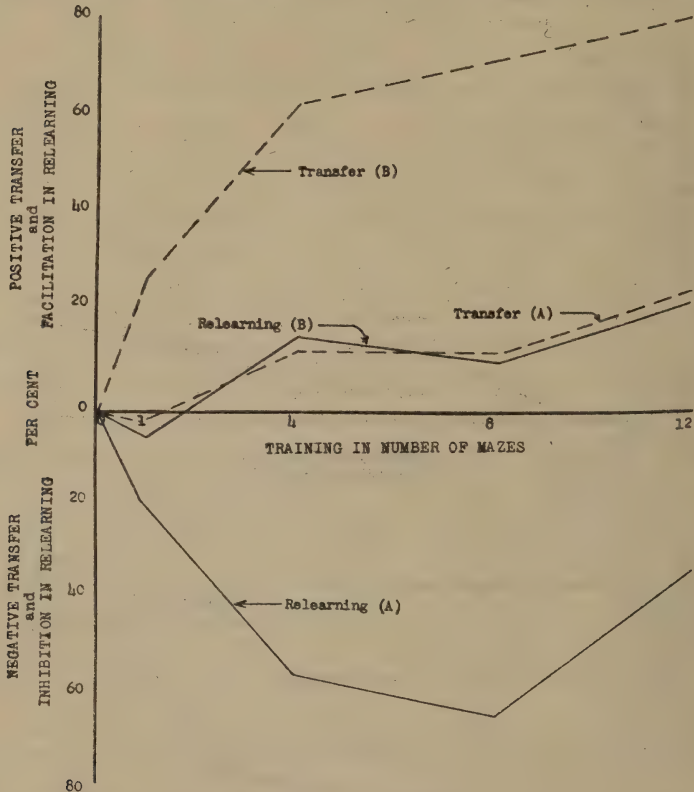


FIG. 32. VARYING RELATIONSHIP BETWEEN TRANSFER (---) AND INHIBITION OR FACILITATION IN RELEARNING (—), IN AVERAGE PER CENT OF EACH BY ALL MAJOR CRITERIA, ON A DIFFICULT MAZE PROBLEM, LEARNED TO MASTERY (MAZE A), AND AN EASY MAZE PROBLEM, INCOMPLETELY LEARNED (MAZE B)

low and rather insignificant degree of positive transfer in learning (maze A); and that a moderate degree of facilitation in relearning is associated with an extremely high and significant degree of positive transfer in learning (maze B). These relations are so clearly evident in the curves of Fig. 32 that, regardless of their interpretation, they may be considered established for the experimental conditions of this study. They seem to be most adequately explained on the assumption that efficiency in relearning is a joint product of three primary factors: (1) retention of the original learning pattern; (2) transfer effects

from the interpolated activities; and (3) transfer effects from the original learning. It is of course obvious that the relearning behavior of an organism is a unitary process, and that in it are largely submerged the respective identities of these component factors. Nevertheless, analysis of them is an important step towards better understanding of the process as a whole. They will first be examined separately, in order to estimate the effectiveness with which each operated in the two parts of the experiment and to determine the probable contribution which each has made to the net results.

With respect to the relative stability of retention alone, there are several reasons for supposing that the more stable memory traces would result from learning to mastery of the longer and more difficult maze A than from the tentorial original learning session on the easier maze B. Although half the animals were successful in achieving at least a single errorless trial by the end of the original ten trials on the latter maze, it is apparent that the general level of learning is very much below that involved in attaining the same criterion on maze A. Aside from the fact that *all* animals learned the latter maze to the criterion, the much greater difficulty of this maze necessarily resulted in a high degree of overlearning for those parts of the pattern mastered most readily. This is so since in a long and difficult maze problem the majority of the animals find one or two blind alleys considerably harder than the rest to eliminate. These characteristically persist in the rat's response, perhaps having been thoroughly learned along with the correct sequence of reactions, and many additional trials are required until they are finally eliminated. In the meantime, of course, the animals are getting a considerable amount of practice on the remainder of the maze, which is run correctly trial after trial and may be very greatly overlearned. This factor could have operated only in a very small measure, if at all, during the ten trials on maze B1. Learning of the relatively difficult maze A may therefore be assumed to have resulted generally in the development of a much more stable, highly integrated learning pattern than is produced by ten trials on the easier B mazes. Since it has been demonstrated that there is an inverse correlation between degree of learning of a task and the extent of its susceptibility to retroactive inhibition (19), the interference effects of interpolated learning would be expected, on the basis of this one factor, to be more effective in breaking up the less stable and less well-learned memory pattern.

Experimental evidence from other sources supports the idea that the retention of the maze A pattern, even if its original learning level were no higher than that of maze B, should be relatively less affected by the interference effects from interpolated learning. It has been amply demonstrated that, within limits short of identity, the greater is the similarity between two learning problems or activities the greater will be the inhibitory effect of the learning of one upon the retention of the other. The maze problems interpolated between the mastery and the relearning of the long and difficult maze A were all short and easy, and, as will presently be pointed out in more detail, were of a sufficiently different type from maze A to develop in the animals a somewhat different maze-running method. The maze problems interpolated between learning and relearning of

maze B, on the other hand, were (with the single exception of maze A) short and easy mazes of the same type as the one originally learned. These short and easy B mazes, being the main interpolated problems in each case, should therefore have produced a significantly greater inhibitory effect upon retention of another highly similar maze B than upon the retention of the relatively dissimilar maze A. The same result would also be expected on the basis of experiments by Siipola and Israel (27) and Melton and Irwin (25), in which there are definite suggestions that the greatest retroactive effect upon memory occurs when the two problems are learned to approximately the same degree.

These theoretical expectations from at least three separate lines of evidence are in direct contradiction to the obtained results. They all point to the probability that cumulative interference effects from interpolated learning activity should operate more effectively upon the memory traces of the easy, incompletely learned maze than upon those of the longer and more difficult maze, learned to a substantially higher degree. According to the efficiency of relearning, the results were in the opposite direction, with the greatest efficiency after cumulative interpolation apparently occurring in the easy maze, and a high degree of retroactive inhibition occurring in the difficult, well-learned maze.

That these discrepancies are more apparent than real, and that the relearning curves for the two mazes do not require fundamentally different explanations, is suggested by further consideration of the transfer effect from the interpolated maze training. The influence of learning B mazes upon mastery of the longer and more difficult maze A is small and statistically unreliable until after twelve such mazes have been learned. Only then, in time and error scores, does the positive transfer effect become fairly significant (C.R.'s of 1.94 and 3.11, respectively). It is therefore probable that the positive transfer effects from learning of the interpolated B mazes were of considerably less importance in relearning of maze A than the retention effect from the original learning of the same maze, at least until after the maximum amount of interpolation had been reached in group R12. Retroactive inhibition from the interpolated tasks would then be expected to interfere with retention in the usual manner, with the resulting retroaction curve of Fig. 32 showing that the detrimental effect is progressively cumulative through eight interpolated mazes. If we assume, on the other hand, that the *retention* of maze B has been pretty thoroughly disrupted by the interpolation of additional highly similar maze patterns, as would be expected on the basis of arguments mentioned above, the transfer curve from the same amounts of training is sufficiently high to suggest strongly that the facilitation in relearning, at least after several interpolated mazes, is very largely based on a similar positive transfer effect from the interpolated learning. The discrepancy between expected and obtained results in relearning would thus disappear, since according to this interpretation it is quite possible for both complete forgetting and facilitation in relearning to have occurred. The positive transfer effects from interpolated learning, being considerably stronger in the relearning of the easier maze B, have become effective in that case after a much smaller amount of interpolated learning. They have operated also in the relearning of maze A, however, although probably not extensively until after the full amount of inter-

olation had been given. The two relearning curves would thus be readily explainable by the same general principles, the major difference being that the peak of the inhibitory effect had apparently been reached earlier in the case of the easier and less well-learned maze, with relatively stronger positive transfer factors then producing a moderate amount of facilitation in relearning. In the absence of more direct evidence (such as would be provided by comparison of these relearning records with learning records obtained under identical training conditions), this interpretation cannot be regarded as established, but it is supported by so much indirect evidence that it can be considered very probable.

The third factor involved in determining the efficiency of relearning is the transfer effect that results from the original learning. Until recently the existence of this type of transfer had been rather generally ignored. Bunch (6) has pointed out that in the measurement of retention by the relearning method due consideration must be taken of the fact that the ability of the subject to relearn a given problem is altered by the transfer effect of having already learned it, *even if* the details of the original learning have been completely lost. That is, there is a positive transfer effect from the first learning which enters into the relearning (savings) score to an unknown extent, and which seems to increase in importance, relative to the detailed memory or retention factors, as the time interval between learning and relearning is lengthened. This latter suggestion follows from the experimental finding that the benefit from learning a similar problem (transfer) remains roughly the same after relatively long intervals of time (up to four months) while the benefit from learning the *same* problem (retention) shows the typical negatively accelerated decline of the forgetting curve until it reaches the level of the transfer effect (4). At this point the detailed memory of the first learning has presumably been so reduced that the advantage of having learned the same problem, rather than a similar one, has been lost, and the savings found in relearning are primarily a function of the general positive transfer effect.

It is very likely that this factor of transfer from original learning has been of less importance in relearning of the easy maze B than in relearning of the more difficult maze A. In the former case the transfer from the interpolated mazes, mostly of the same type as the original, would be supplemented somewhat perhaps by transfer from the original, but the relative effect would not be expected to be very great, especially in the groups with more interpolated mazes. In relearning maze A, however, transfer from the original learning would seem to be of greater importance, especially in the conditions of more interpolation, where a greater amount of forgetting of original detail would be expected. Although its influence cannot be separated from that of the retention factor, this may have played a large part in keeping the relearning scores of the R groups so consistently above the transfer scores of the T groups.²⁷ In the two control or rest conditions,

²⁷ The relearning records of all Retroaction groups were, without exception, in terms of trials, time and total errors, superior to the learning records of all Transfer groups. In total errors, the measure which showed the largest and most regular transfer effect, the differences were especially significant, with the *lowest* C. R. being 2.66 and all but two of the remaining twenty-five comparisons having C. R.'s from 3 to 9 and 10.

the extent to which this factor has operated is again indeterminate, but its influence was probably *relatively* greater in the relearning of maze B, where retention would be expected to be weak. For this reason, it may well have been instrumental in holding the advantage of maze A over maze B in percentage savings to about 10 per cent, since on the basis of retention alone the supposedly higher stability of maze A memory traces might be expected to result in a larger advantage.²⁸

The way in which these three factors have probably interacted in relearning of each type of maze may now be summarized. In maze A the loss in retention may be considered roughly proportional to the amount of interpolated activity although it is not clear from the data whether the decline in retroactive inhibition with continued interpolation is due to the leveling off of forgetting plus the increment in transfer effect from the interpolation, or merely to the latter factor alone. However, from the relatively small increase in the transfer curve after similar preliminary training on twelve mazes, it does seem likely that there was also involved an actual leveling off of the curve of forgetting. In the case of maze B, it is highly probable that the actual forgetting increased very rapidly with interpolation, and that the facilitating effect was due primarily to the large increments in transfer effect from the training on the interpolated tasks. The transfer effect from the original learning was probably of considerably less importance in relearning of maze B, which was just another short and easy maze, than it was in relearning of maze A, especially after a greater amount of interference from interpolated learning, since the general transfer of training involved in learning the longer maze would be expected to be of considerable value in relearning, even if the detailed pattern of the maze were completely disrupted.

These results serve to throw some light on the maze study reported by Ho (13) and reviewed in the introduction (p. 2). Superior relearning records were made in every case by groups of rats which were given varying numbers of interpolated trials, on a second maze, after having *mastered* the first. Although it is impossible to evaluate with any precision the influence of these factors in Ho's study, it is pertinent to note that his results, reported as facilitation in *learning* from transfer, are in line with those of this experiment and indicate again the very intimate relationship between interference in memory and transfer of training.

Thus far in the discussion brief mention only has been made of the relationship between negative and positive factors in transfer. Their importance in determining the net amount and the direction of the final transfer effect is obvious. It has been demonstrated that learning to make new responses to old stimuli results most reliably in a net negative transfer or interference effect (*cf.* especially Bruce, 3). Bunch (7) has shown that when rats are forced to master two antagonistic habits in a simple maze situation the high degree of negative transfer (almost 50 per cent in errors) found if the two problems are learned in immediate succession gradually disappears as the time interval is lengthened. Two weeks

²⁸ Savings percentages in time and errors were, for group RO, 67 and 78 per cent respectively, and for group BRO, 58 and 68 per cent.

after mastery of the first habit a 20 per cent positive transfer is found, in errors, when the antagonistic habit is learned. These results are best explained, according to Bunch (7, p. 196), by postulating in transfer phenomena the independent variability of two major kinds of determining conditions: those which represent the detailed pattern of learned responses from the first task, and those which represent the more general learning (set, technique, emotional adaptation, etc.) from the first task. If the specific, detailed memory patterns are assumed to fade more rapidly with time (or cumulative interpolated activity), as such details are ordinarily found to do, the shift in net transfer effect from negative to positive in the simple learning situation mentioned above as well as in more complicated ones, is seen to be a result of the increasing relative influence in transfer of the general factors.

In the present study, comparison of the first trial relearning records of maze B with relearning records for the first five trials provides a concrete example of the way in which positive transfer factors, probably of a general nature, apparently become progressively stronger for all conditions of interpolation as relearning continues. This trend is evident in Figs. 22 and 23 (pp. 40 and 41). Even in the first trial, however, the net result is inhibitory only for those groups with the least amount of interpolated training, and is definitely facilitating for the group with twelve interpolated mazes. These results are in direct agreement with the general tendency, noticed especially in recent reports (25, 26, 29), for relearning measures in human verbal learning to show less retroactive effect than recall measures (*cf.* p. 6).

Further evidence of the changing relationship between specific and general transfer factors may be adduced from comparison of maze A relearning records. After twelve interpolated mazes animals relearning the difficult maze A are still making as many errors in the blind pathways but are learning the maze in considerably less total time, and in fewer trials, than animals which had only eight interpolated mazes. The former fact suggests that interference effects from the continued accumulation of new learned responses have not been reduced; the improved scores in time and trials may therefore be interpreted as meaning that the four additional mazes have provided a significant increment in some of the general, positive transfer factors.

Concrete examples of the way in which general factors of method may vary independently, producing either positive or negative effects within the same learning activity, may also be found in the present study. The total errors made in relearning of maze A by the R animals were analyzed into three types, as shown in Fig. 2 (p. 13), depending upon whether they were made in the true pathway (type T), blind alley entrance (type B), or blind alley end (type E). It was found that the leveling off of the total errors curve and its failure to decline after twelve interpolated mazes, were a combined function of the progressive increase made in number of type T and type B errors, and the simultaneous decrease in the number of type E errors. The corresponding transfer curves revealed similar trends, type B errors showing little reduction with continued training, type T even a slight but insignificant increase, and type E a continuous

and highly reliable decrement (*cf.* Figs. 14 and 16, pp. 27 and 31). In terms of the transfer components described above, type B errors, resulting mainly from incorrect reactions at points of choice, may be considered a measure of the amount of interference among the specific detailed response factors which have been built up through training in varying numbers of different maze patterns. Thus it is not surprising that this type of error should show progressive increment with increasing amounts of interpolated maze training, and small reduction after similar amounts of preliminary training on the same B mazes. Type T and type E errors, which show divergent tendencies, may both be considered measures of more general transfer factors of technique or method. This will be clarified by reference to Figs. 1 and 2 (pp. 12 and 13), which show a short segment of the maze A pattern and a typical B maze. It will be noticed that in maze A the multiple-T pattern insures continuous free passage to the animal so long as he does not stay in the ends of a single blind alley. On the other hand, the maze E patterns, owing to the nature of their construction, frequently involve two or three or more units from which there is only a single correct exit and in which the animal is forced to remain until he makes the correct reaction. Learning to get out of such "pockets" is therefore largely a matter of avoiding useless exploration of the ends while retracing within the main pathway until the correct sequence of turns is finally made. The learning method which this encourages may be seen to transfer, after varying amounts of B maze training, to the learning or the relearning of maze A, in that the type E errors (representing the tendency to continue the useless exploration of blind ends) are very much reduced, while type T errors (representing the tendency to retrace within the main runways) are made with increasing frequency both in learning and relearning of the larger maze problem.²⁹

When the relearning curves of Fig. 32 are considered in the light of the various transfer factors involved, it becomes apparent that retroactive inhibition from subsequent learning of a similar sort cannot be regarded as a sufficient measure, in and of itself, of the decrement in retention that takes place in relearning. Transfer of training has been found to set a definite limit upon the amount of retroactive inhibition that results when interpolated learning activity becomes cumulative to a large extent. The curve of forgetting, as it is measured by relearning efficiency, has not been found to drop progressively and continuously with increasing amounts of interpolation. A point has been reached after which further interpolation has a beneficial rather than a detrimental effect. This finding is in agreement with evidence previously reported (5) that after the retention curve has been lowered to a certain point further interpolation has a facilitating effect. In the latter case that was accomplished only after four months of normal everyday activities; in the present study it was accomplished within fifteen days by concentrated interpolation of highly similar learning materials. In the present study, moreover, the amount of interpolated training

²⁹ This factor would also operate to increase somewhat the number of blind pathway errors, since the blind stems as well as the true pathway runways are involved in the re-tracing activity of B maze training.

that was required before retroactive inhibition began to decline, as in relearning of the more difficult maze, or changed to facilitation, as in relearning of the easier maze, is directly correlated with the amount of positive transfer effect which occurred when corresponding quantities of interpolated training were given as preliminary learning. In view of the fact that positive transfer from the interpolated training appears to set a definite limit upon the amount of retroactive inhibition in relearning that can be produced by cumulative interpolated learning activity, a definite limitation to the theory that forgetting is caused by retroactive inhibition is indicated.

SUMMARY AND CONCLUSIONS

A widely held point of view in the field of memory at the present time is that the explanation of forgetting is to be found in the increase in interpolated activity that accompanies the passage of time. If this is true, successive accumulation of additional amounts of interpolated, similar activities ought to produce corresponding increments of retroactive inhibition in retention. On the other hand, some data from the experimental studies of transfer of training suggest a limitation on the amount of retroaction in relearning that may be produced by increasing amounts of interpolated training on similar material. The present study is designed to test the implication from the former view, and to compare the influence of cumulative training upon relearning with its effect upon initial learning of the same problem.

In order to determine quantitatively the manner in which the amount of retroactive inhibition in retention is a function of the amount of interpolated activity, five equated groups of approximately twenty-five white rats each were given varying amounts of training on short maze problems following the learning of a more difficult maze and preceding its retention test. Four additional groups were given corresponding amounts of the same training before the original learning of the more difficult maze problem. The effects of the same amounts of cumulative training upon retention, in the first case, and upon learning, in the second, can thus be directly compared.

The mazes used were a large multiple-T water maze and twelve shorter water mazes of similar basic construction. The interval between learning and relearning was fifteen days. Within this period 0, 1, 4, 8 or 12 water maze problems were interpolated, ten trials daily being given on each regardless of the degree of learning attained. Thus the cumulative transfer of training from the various short mazes to the difficult maze can be compared with cumulative retroactive effect of these mazes upon retention of the difficult one.

The conclusions from the study may be summarized as follows:

1. Cumulative transfer is concluded to have occurred throughout a series of twelve successive, highly similar learning problems, since animals which are first given training on twelve short mazes show, in some respects, consistent improvement throughout the whole series.
2. Recall measures (first trial relearning scores on the short maze) have been found to show considerably more retroactive effect than relearning measures.

This is in confirmation of recent similar results from studies of human verbal learning.

3. Retroactive inhibition in the retention of the long and difficult maze problem, originally learned to mastery, increases to a maximum with increasing amounts of interpolated training through eight mazes, and then declines when four additional problems are interpolated.

4. Retroactive inhibition is negligible after small amounts of interpolation, and facilitation occurs after larger amounts, in the retention of a short and easy maze problem, originally incompletely learned and highly similar to the interpolated mazes.

5. Associated with the increase of retroactive inhibition to a maximum in relearning of the difficult maze is a generally insignificant degree of positive transfer, found in the original learning of the maze when the same problems as are used for interpolated training are given as preliminary training.

6. Associated with the negligible retroaction and the actual facilitation in relearning of the short and easy maze is a large and highly significant degree of positive transfer in original learning from the same mazes when given as preliminary training.

7. Comparison of the points of largest increment in positive transfer and the points of greatest improvement in relearning efficiency, suggests in each case that the decline in retroaction is a function, in large part at least, of a pronounced increase in positive transfer from the interpolated learning to the relearning.

8. These results point to a definite limitation in the explanatory value of retroactive inhibition as the major factor in forgetting, since such inhibition in relearning does not become progressively greater with the continuous accumulation of additional amounts of interpolated training.

9. It is tentatively concluded that transfer of training, especially from the interpolated learning, is the important factor in thus limiting the amount of retroactive inhibition that can be produced in relearning by interpolated learning activities.

Further detailed interpretation of the results is offered in terms of transfer of training. Relearning efficiency is considered as the combined function of at least three important influences: (1) retention of specific detailed responses from the original learning; (2) transfer of training factors from the interpolated learning; and (3) transfer of training factors from the original learning. The way in which positive and negative factors of general and specific nature interact in producing the net transfer effect, and therefore in largely determining the efficiency of relearning, is discussed, and some pertinent examples are cited from the data.

REFERENCES

- (1) BRITT, S. H.: Retroactive inhibition: a review of the literature. *Psychol. Bull.*, 1935, **32**, 381-440.
- (2) BRITT, S. H., AND BUNCH, M. E.: Jost's law and retroactive inhibition. *Amer. Jour. Psychol.*, 1934, **46**, 299-308.
- (3) BRUCE, R. W.: Conditions of transfer of training. *Jour. Exper. Psychol.*, 1933, **16**, 343-361.

- (4) BUNCH, M. E.: A comparison of retention and transfer of training from similar material after relatively long intervals of time. *Jour. Comp. Psychol.*, 1941, **32**, 217-231.
- (5) BUNCH, M. E.: The efficiency of retention of a rational learning problem under (1) normal conditions and (2) conditions of interpolated learning, for long intervals of time. *Psychol. Bull.*, 1938, **35**, 691 (abstract).
- (6) BUNCH, M. E.: The measurement of retention by the relearning method. *Psychol. Rev.*, 1941, **48**, 450-456.
- (7) BUNCH, M. E.: Transfer of training in the mastery of an antagonistic habit after varying intervals of time. *Jour. Comp. Psychol.*, 1939, **28**, 189-200.
- (8) BUNCH, M. E., AND LANG, E. S.: The amount of transfer of training from partial learning after varying intervals of time. *Jour. Comp. Psychol.*, 1939, **27**, 449-459.
- (9) BUNCH, M. E., AND McTEER, F. D.: The influence of punishment during learning upon retroactive inhibition. *Jour. Exper. Psychol.*, 1932, **15**, 473-495.
- (10) BUNCH, M. E., AND WINSTON, M. M.: The relationship between the character of the transfer and retroactive inhibition. *Amer. Jour. Psychol.*, 1936, **48**, 598-608.
- (11) FOUCAULT, M.: Introduction à la psychologie de la perception. Experiences sur l'oubli ou sur l'inhibition regressive. *Rev. des Cours et Conferences*, 1913, **21**, Series 1, No. 5, 444-454.
- (12) GIBSON, E. J.: Retroactive inhibition as a function of the degree of generalization between tasks. *Jour. Exper. Psychol.*, 1941, **28**, 93-115.
- (13) HO, Y. H.: Transfer and degree of integration. *Jour. Comp. Psychol.*, 1928, **8**, 87-99.
- (14) HUNTER, W. S.: Learning: II. Experimental studies of learning. In Murchison, C. (Ed.) *The Foundations of Experimental Psychology*. Worcester: Clark University Press, 1929.
- (15) LAHEY, M. F. L.: Retroactive inhibition as a function of age, intelligence, and the duration of the interpolated activity. *Cath. Univ. Amer. educ. Res. Monogr.* 1937, **10**, No. 2, 93 pp.
- (16) LIN, C. T.: The factors of similarity and identity in retroactive inhibition. *Chin. Jour. Psychol.*, 1936, **1**, 21-53. (*Psychol. Abstr.*, 1937, **11**, 658.)
- (17) McGEOCH, J. A.: Forgetting and the law of disuse. *Psychol. Rev.*, 1932, **39**, 352-370.
- (18) McGEOCH, J. A.: The influence of degree of interpolated learning upon retroactive inhibition. *Amer. Jour. Psychol.*, 1932, **44**, 695-708.
- (19) McGEOCH, J. A.: The influence of degree of learning upon retroactive inhibition. *Amer. Jour. Psychol.*, 1929, **41**, 252-262.
- (20) McGEOCH, J. A.: *The psychology of human learning*. New York: Longmans, Green and Co., 1942. Pp. 663.
- (21) McGEOCH, J. A.: Studies in retroactive inhibition: VII. Retroactive inhibition as a function of the length and frequency of presentation of the interpolated lists. *Jour. Exper. Psychol.*, 1936, **19**, 674-693.
- (22) McGEOCH, J. A., McKINNEY, F., AND PETERS, H. N.: Studies in retroactive inhibition: IX. Retroactive inhibition, proactive inhibition, and reminiscence. *Jour. Exper. Psychol.*, 1937, **20**, 131-143.
- (23) McKINNEY, F., AND McGEOCH, J. A.: The character and extent of transfer in retroactive inhibition: disparate serial lists. *Amer. Jour. Psychol.*, 1935, **47**, 409-423.
- (24) MATOUSEK, M. A.: Reproductive and retroactive inhibition as a function of similarity in the recall and recognition of paired associates. *Cath. Univ. Amer. educ. Res. Monogr.*, 1939, **12**, No. 1, 42 pp.
- (25) MELTON, A. W., AND IRWIN, J. McQ.: The influence of degree of interpolated learning on retroactive inhibition and the overt transfer of specific responses. *Amer. Jour. Psychol.*, 1940, **53**, 173-203.
- (26) MELTON, A. W., AND VON LACKUM, W. J.: Retroactive and proactive inhibition in retention: evidence for a two-factor theory of retroactive inhibition. *Amer. Jour. Psychol.*, 1941, **54**, 157-173.

- (27) SIIPOLA, E. M., AND ISRAEL, H. E.: Habit-interference as dependent upon stage of learning. *Amer. Jour. Psychol.*, 1933, **45**, 205-227.
- (28) SWENSON, E. J.: Retroactive inhibition: a review of the literature. Minneapolis: Univ. of Minnesota Press, 1941.
- (29) THUNE, L. E., AND UNDERWOOD, B. J.: Retroactive inhibition as a function of degree of interpolated learning. *Jour. Exper. Psychol.*, 1943, **32**, 182-200.
- (30) TWINING, P. E.: The relative importance of intervening activity and lapse of time in the production of forgetting. *Jour. Exper. Psychol.*, 1940, **26**, 483-501.
- (31) VÉLINSKY, S.: La certitude associative. *La base de la psychologie de l'apprentissage. L'Annee Psychol.*, 1927, **28**, 140-185.
- (32) WARD, L. B.: Reminiscence and rote learning. *Psychol. Monogr.*, 1937, **49**, No. 220.
- (33) WATSON, B.: The similarity factor in transfer and inhibition. *Jour. Educ. Psychol.*, 1938, **29**, 145-157.
- (34) WEBB, L. W.: Transfer of training and retroaction. A comparative study. *Psychol. Monogr.*, 1917, **24**, No. 104, Pp. 90.
- (35) WILTBANK, R. T.: Transfer of training in white rats upon various series of mazes. *Behav. Monogr.*, 1919, **4**, No. 17.
- (36) WOODWORTH, R. S.: *Experimental Psychology*. New York: Holt and Co., 1937. Pp. 889.

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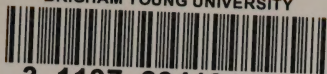
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